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Report of EIGHTH DRY BEAN RESEARCH CONFERENCE

Bellaire, Michigan
August 11-13, 1966

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

THE EIGHTH DRY BEAN RESEARCH CONFERENCE was held August 11-13, 1966, in Bellaire, Mich. It was attended by bean growers, shippers, and processors from various growing areas, as well as by research and extension workers from State and Federal agencies. The program was composed of 14 papers reporting results of current research on the production, marketing, and utilization of dry beans. On August 11, Michigan State University conducted a tour of Food Science, Plant Pathology, and Soil and Crops Science laboratories, as well as bean research plots where current work on genetics and zinc deficiencies was reviewed. In the evening a special symposium was held at Delta College on production research. A display of new bean products, such as quick-cooking dry lima beans and various bean powders, shown on August 12, was a highlight of the conference.

Sponsors were the National Dry Bean Council, Michigan Bean Shippers Association, Michigan State University, and the Western Utilization Research and Development Division, Agricultural Research Service, U.S. Department of Agriculture.

Wayne Van Vleet, President, National Dry Bean Council, served as General Chairman. M. W. Adams of Michigan State University and Bernard Feinberg of Western Utilization Research and Development Division, USDA, were program co-chairmen. The advice and assistance of M. J. Copley, Director, Western Utilization Research and Development Division, Agricultural Research Service, USDA, Albany, Calif.; Maurice Doan, Executive Secretary-Treasurer, Michigan Bean Shippers Association, Saginaw; and Carl W. Hall, Michigan State University, East Lansing, are gratefully acknowledged.

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March 1967

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LEGUMES AND A HUNGRY WORLD

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From a chapter written by R. F. A. Dean of Uganda for a book which I edited some years ago, the statement "that legumes will present one of the most important sources of protein for the future and their utilization must dominate any discussion of man's use of plant proteins," might well open this discussion. I became further intrigued with legumes when I ran into the speculation on how ancient American civilizations developed. The story goes that as long as the major source of food was corn, large urban populations could not form and survive, because there was insufficient protein to supply their needs. But when beans came into the agricultural pattern, then corn and beans together made for an adequate diet and permitted large concentrations of people so necessary to sustain a high culture.

Legumes remain a major source of protein throughout the world. It is estimated that humans consume 8.5 million tons of protein annually from legumes as compared to 40 million tons from cereals and 22 million tons from animals. I do not know how much of the 8.5 million tons is solely non-oilseed legumes. But I would suspect that this is a substantial amount. Non-oilseed legumes are a major protein crop in India; over 10 million tons are produced--more than tenfold higher than in any other country. Since it is yet a question as to whether soybeans can assume an important role in India, these legumes are a critical source of protein supplements.

Let us first discuss the program to encourage new food industries in developing countries to combat protein malnutrition and then try to comment on the position of legumes.

As a beginning, we might review what is known about the problem. There are actually two problems and they are related: (a) There is the problem of undernutrition--there is not enough to eat and there are not enough calories. (b) There is the problem of malnutrition--the quality of the food is inadequate. We will confine our discussions of malnutrition to protein malnutrition,

although we recognize fully that there are instances of vitamin and trace mineral malnutrition as well.

Some ideas of the orders of magnitude of the deficiencies are available. It is estimated that the deficiency in calories (undernutrition) is of the order of 54 million tons of grain. It is interesting to note from testimony of Secretary Freeman that some time in the 1980's the free world will be unable to meet the deficit of grains anticipated by the increasing world population. The estimate of protein shortage is of the order of 5 million tons of animal protein equivalent per year based on standards of a UN committee.

The frightening aspect of this whole matter is that whereas western society has increased constantly its efficiency of food procurement and per capita supplies have increased, the developing countries have barely if at all kept pace with their population growth so that their per capita food supplies have increased but little and in some instances have decreased. Two obvious approaches are to limit population growth and to increase food supplies by whatever means possible. In the interim those countries that have a capacity for producing food will have to continue to help make up this deficit.

Most of the effort in helping the developing countries to improve their food supplies is what I might call the conventional approach. This brings their agriculture closer to the level of efficiency of ours by better practices, by the proper use of fertilizer, by planting the best kinds of seeds, by breeding more efficient animals, and by minimizing destruction from pests. These efforts are by far the most important approach and are being pursued.

Some feel that this is enough. But an examination of the trend seems to indicate that every possible approach will be needed to bring the food supply to an adequate level. Hence, one ought to consider additional approaches. In this latter connection I address this conference.

It is possible to increase the availability of food by upgrading the quality of existing foods; secondly, it is possible to increase the efficiency of utilization of our photosynthetic process by designing and creating protein foods directly from plant sources which may have the quality and character of proteins from animal sources and, therefore, add to our supply of animal protein equivalent. Let us take these ideas one at a time.

The major source of protein for man is the cereal proteins which supply more than 40 million tons of protein a year. Their quality is not the equal of animal protein nor in all cases is the

concentration adequate for adults, let alone children. If it were possible to increase the protein quality and/or the quantity by supplementing either with protein concentrates or with amino acids in a way not to interfere with normal food channels, one could make a large immediate contribution to the protein supply of the world. If for example the quality of all the protein in the cereal grains were improved by 10 percent, this would be equivalent to adding 4 million tons of protein to our supply. This is not an unreasonable goal. There are now available protein concentrates which could perhaps be added in sufficient concentration to make an impact both in quality and quantity without changing the properties of flour for breadmaking or the corn flour for tortilla-making. There are now available amino acids at prices low enough to be considered as additives to the cereals for purposes of improving quality of the protein. In most cereals, lysine is the first limiting amino acid; the addition of lysine might be expected to improve the quality markedly.

This approach is being investigated seriously as a major means of improving protein supply. Success would have an additional advantage in that it would enable us to use protein-poor sources of food to make up the calorie deficit. Under a regime where the protein picture is improved, it would not be necessary to consider the caloric shortage in terms of grain alone but one might also consider other sources of calories as available to solve the problem of undernutrition.

The second approach is to design new foods high in protein content and high in quality and acceptability. Examples of such foods are baked products, cereal-protein mixtures, beverages, textured products, and spreads. It is now possible to consider that protein beverages can be designed to be equal in nutritional quality to milk beverages and be acceptable and tailored to the diverse tastes of different societies. It is not unreasonable to assume that every child in the world could have a protein beverage, milk, or otherwise. It is not unreasonable to assume that textured products could be made chewy and flavorful. These can be served with basic foods to increase the protein quality and human interest. The raw material for these products could be protein concentrates from seeds such as soybean, cottonseed, and peanuts, could be fish protein concentrate if it were approved by Food and Drug Administration, or proteins from yeast and other microorganisms which are rapidly becoming of great potential interest.

How do we stand in this program? We have held discussions with the American scientific community to obtain the best advice on how to conduct feasibility experiments on amino acid fortification of cereals. Such tests hopefully will be started in the near

future. We have encouraged the food industry to consider projects for new foods in developing countries. There has been considerable interest; we already have a number of proposals which we are now discussing within USDA and AID to determine how these could be facilitated.

Now let us turn back to the legumes. We know that legumes are now making an important contribution to the world protein supply. Can this contribution be improved, increased, and made more versatile? It cold probably be improved by removing some of the physiological factors which are associated with certain legumes. That means that we must know more about these factors and perhaps learn how, if possible, we could eliminate them by breeding. I note that you are devoting considerable time to this subject at this meeting.

But, let us consider the major difference in the handling of legumes generally as compared to oilseed legumes in particular. Specifically, let us consider the differences in handling legumes compared to the handling of soybeans. Soybeans are not utilized as is; they are processed and are presented to the consumer in a form entirely different from the natural one. Processing does a lot of things: It concentrates protein--the protein content of soybeans can be increased from 40 to 50 percent, or 70 or 100 percent, depending on the process; the protein content of peanuts can be increased to 50 or 100 percent depending upon processing conditions. Processing often improves quality, primarily by removing the deleterious substances; thus, the heating of soybeans in processing renders the product edible to nonruminants and humans. The formation of tofu, which is the ancient process for preparing soybean curd, has made it possible for orientals to utilize soybeans as an important part of their protein economy. Processing makes it possible to nullify the disadvantage of gossypol in cottonseed.

Processing could put a material in a form suitable for consumption by man. Thus, one could make texturized products from soybeans that are attractive to animal-protein-loving man or one can transform these into ingredients of beverages, another form preferred for consumption. And, finally, processing generates other useful products. Actually in the modern processing of oilseeds, proteins came in through the back door because the original objective was to isolate the more expensive oil. Only in recent times has the protein become the more important constituent of soybeans economically and similarly for other oilseeds.

We could examine, in theory at least, what the kind of processing I am talking about might do for the non-oilseed legumes in which you are particularly interested. We could, of course,

make a protein concentrate or isolate from such legumes. Attempts have been made to do so for some legumes, but I have never been satisfied that this has a practical base; it merely serves to emphasize the enormous simplicity of making protein concentrate from oilseeds by removing the oil. But one can increase protein content by removing gums. I recently heard of an instance in West Pakistan where Sesbania aculeata (dhaincha) which contains about 27 percent protein, can be increased in protein content to 50 percent by removal of gums. This may be a practical approach.

Another way of handling non-oilseed legumes would be to blend these with other materials of higher protein content in order to make a suitable protein food. One example is a blend of chick pea, sesame, and soy flour as described by Guggenheim. One could also add fish-protein concentrate or soy-protein isolate to these materials to raise their protein content. One could consider putting these in forms that would give them more versatility and at the same time blend them in with other sources of protein. For example, I have seen spun-textured materials from legumes. Such spun materials could be eaten with rice in large quantities and could definitely improve the protein intake. Or, as I mentioned earlier, one could possibly design beverages with non-legume proteins as a base to which can be added other sources of protein to increase the protein content to a desired value. And of course processing could reduce or eliminate some of the deleterious factors that must now be bred out of legumes to increase their usefulness. This is the solution of a problem by cultural evolution rather than by genetic evolution.

The fact that there is no oil product to add economic value in processing legumes is a deterrent. And this is, no doubt, the reason why there is little if any interest in processing legumes to improve protein value. Whether there is any other product equivalent in value to oil, such as gum, is questionable. So, is it questionable whether the increased protein value and versatility in itself will make processing economically interesting for those who are interested in expanding the role of legumes. I think that we will be forced to look seriously at the potential for extended uses of legume protein in countries like India where large quantities of protein, as soybeans, are not available.

We have been asking the American food industry to contribute its enormous know-how and experience to the design of solutions to the problem of world protein malnutrition--solutions which will be economically viable. The legume people too may have something to contribute. Is it possible to design new approaches to expanded use of legume proteins through processing?

Bibliography

Altschul, A. M. (ed.). _Processed Plant Protein Foodstuffs_, Academic Press, New York, 1958.

______________________ _Proteins, Their Chemistry and Politics_, Basic Books, New York, 1965.

______________________ Edible Seed Protein Concentrates: Their Role in Control of Malnutrition. _Israel J. Med. Science_ 1: 471, 1965.

Food and Agriculture Organization of the United States. Report of the FAO/CCTA Technical Meeting on Legumes in Agriculture and Human Nutrition in Africa. Rome, Italy: Food and Agriculture Organization of the United Nations, 1959.

Guggenheim, K., and Szmelcman, S. Protein-Rich Mixture Based on Vegetable Foods Available in Middle Eastern Countries. _J. Agr. Food Chem_. 13: 148, 1965.

Montgomery, R. D. The Medical Significance of Cyanogen in Plant Foodstuffs. _Amer. J. Clin. Nutr_. 17: 103, 1965.

Patwardhan, V. N. Pulses and Beans in Human Nutrition. _Amer. J. Clin. Nutr_. 11: 12, 1962.

Whyte, R. O., Nilsson-Leissner, G., and Trumble, H. C. Legumes in Agriculture, Rome, Italy: Food and Agriculture Organization of the United Nations, 1959.

CAN DRY BEAN CONSUMPTION BE INCREASED?

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You've posed me the question: Can dry bean consumption be increased? And rather than keep you in suspense for my alloted 20 minutes while I review the evidence and present the conclusion at the conclusion all in logical order, I'd like, instead, to start with the answer and work backward.

Yes, dry bean consumption can be increased. Yes, indeed... most emphatically in the affirmative. The job can be done. But the answer, as you very well know, is not contained in just that one word. It's not simply yes...it's yes, but...and yes, if.

Yes, we can increase dry bean consumption, but we cannot do it with simple, unadorned dry beans no matter how much WE admire their good old-fashioned virtues, for the plain fact is that consumers DON'T, and if you don't give the ladies what they want, you have plenty of competitors who will.

Yes, we can increase dry bean consumption by a moderate amount if we'll listen to the Missus and pay attention to what she says about beans and why she does or doesn't like them. In market studies, we sometimes forget that the "why" of product performance is just as significant as the "what." Market-share data tell us the "what." Consumer attitude surveys tell us some of the "whys."

In the case of beans, the "what" of product performance is pretty impressive. Beans are our leading canned vegetable...in fact, beans are the fourth largest item packed in tins. And now, in addition to the many colorfully labeled canned bean products and the familiar film bags of dry beans, sales totals are being boosted by laminated envelopes of bean soup mix and lithographed boxes of "instant" or "quick" beans with or without seasonings to match the mood of the do-it-herself or the hurry-up cook. Bean dips, bean chips, bean powders, and bean flours are all in the offing. Industrywide efforts to encourage the growth of a variety of bean offerings are needed, for it is probably through variety that per capita consumption increases will be achieved.

This is probably the place to clear up what might be a misunderstanding of terms. When I was invited to present a paper to this gathering, in my consumer-oriented innocence I regarded beans as beans. I made no distinction between dry beans and canned beans ...after all, they all started life together. For the purposes of

our discussion today, I want to ask you to look at beans from a consumer's point of view; for in the last analysis it is consumer decisions to buy and serve beans that will increase per capita consumption. I am convinced that when consumers buy beans they select the product that comes closest to filling the need they have in mind and they don't really care whether it's dry or canned or how it's processed so long as it does the job.

Let me talk to you a bit about consumers--those ladies whose actions in the market place are so important to our future. Michigan State University's Consumer Marketing Information Program conducts two studies each year involving about 1,500 consumers in 8 major marketing areas across Michigan. Here, both urban and rural populations are represented and the women record their attitudes toward and preferences for form, taste, price, packaging, and many other aspects of the various food products presented for their judgments. Sometimes their level of knowledge about food laws, grades, and standards are measured, and sometimes we find that what we had thought were standard concepts are not widely understood at all.

Independent of the Statewide consumer surveys are two more surveys each year conducted in Detroit by our Department of Agricultural Economics. The Detroit group is a systematic random sample chosen to represent demographically the general population of the Detroit metropolitan area. The women (and some men, incidentally, for men are becoming more common in supermarkets every year) have an average of 12 to 13 years of education, an income between $4,000 and $10,000 a year, and are between 30 and 45 years of age. Together, the two panel groups represent a pretty good cross section of the food buying public.

For 2 years we've been quizzing the consumers in Detroit and selected out-of-State areas to find out who buys navy beans, in what form they buy them, how they serve them, how often they serve them (more in summer? winter? both the same?), and why they serve them.

What did they tell us? Why DO they buy and serve beans? Because they're economical? According to our studies, all other reasons are more important to Michigan consumers. Only 1 respondent out of 124 questioned in Detroit last May listed low cost per serving as her most important reason for serving canned pork and beans. We set a little trap for this group suspecting that they might feel reluctant to give such a clearly economic reason. We suggested that another reason for serving beans might be that they were a good source of protein for the money. This says "economical" but in a more diplomatic way, and yet this was their second least important reason for serving beans. Another group

of consumers was asked to view a display of three forms of beans and asked which kind they would be most likely to buy. Canned beans, a 1 pound 12 ounce can for 24 cents, was the first choice. In second place was a 10 ounce box of quick, pre-cooked beans at 26 cents--more than twice the price of the canned product and unfamiliar to many of the respondents. Trailing along behind came dry navies--a bargain at 14 cents a pound but with few takers.

If price doesn't matter too much, what does? Well, family preference is important. Our consumers said they bought and served beans because the family liked them. Families apparently liked canned pork and beans so well that 93 percent of the Detroit group and 99 percent of the Saginaw group claimed to have bought them in the last 12 months. Miss Mary Zehner, Agricultural Economist for Michigan State University, who is supervising the bean attitude studies, cautioned me to be sure to tell you that she believes the respondents did not make varietal distinctions when they reported canned bean purchases at the 93 and 99 percent levels and they must be including kidneys, pintos, and products other than canned pork and beans.

Family preference, then, is reason number one for buying and serving beans. Convenience is reason number two. The two reasons taken together make a pretty strong argument for the possibility of increasing bean consumption in the United States in the years ahead, for almost all indexes assure us that convenience foods are and will continue to be among the fastest climbers in the food business.

A word here about convenience foods. What we perceive as "convenience" may not be at all what the homemaker is thinking about. The editor of Food Business Magazine suggests that homemakers customarily identify convenience in terms of their own experience in the kitchen--in other words, their age. Few homemakers would include canned soup in a list of convenience foods although it certainly qualifies on all counts. It's just that it's been around so long that it's regarded as the standard form of the product. In the same fashion, the younger homemakers probably do not single out instant mashed potatoes or even canned beans as convenience products either because they've been readily available for all the time they've been shopping and cooking.

Homemakers value the convenience features of these foods and buy them because they are quick and easy to use. But they also identify and buy as "convenience foods" products that still require a certain amount of preparation beyond heat and eat. If the tiresome routine preparation work is done leaving only the more glamorous and creative efforts of seasoning and spicing to bring the product up to family standards, a food is very likely to be considered "convenient" by homemakers.

There's even such a thing as being too convenient. When early cake mixes were put on the market many of the housewives resisted them, consciously or subconsciously, because they felt the absence of a sense of participation in mixing the cake batter. When manufacturers responded to this feeling and marketed new mixes which required the addition of one or two eggs to the powdered cake mix they met with a much more favorable response.

You can't push these gals too far or too fast even when you know you're right...not if you want to sell the product. You've got to listen and then maybe adjust <u>your</u> thinking if you can't adjust hers. We encountered some of this stubbornness when we quizzed our consumer panels as to their picture of beans as a nutritious food. As nutritionists and home economists, we're fond of pointing out that beans are a good source of protein and a main dish-substitute for meat. So, we led the ladies a little. In effect, we said "Would you believe beans are a protein food and can be served as a main dish instead of meat?" They, in effect, replied "We mostly (77 percent) think they're a vegetable. If we serve them as a main dish (22 percent) we're as likely as not to add meat--even if we don't have to." If you think that the nutritional advantages of beans are a good selling point, the story can probably be told. William Sebrell, distinguished professor of Public Health, predicts that nutrition will some day be a potent appeal in selling food. Keeping their families physically fit is an important goal for most women. Food has always been surrounded with emotional appeals and this is a key one.

Today, there is another feature that is very important to consumers of beans, both dry and canned, and surely for the new forms soon to be introduced. This is quality. More than 75 percent of our consumer panelists mentioned quality characteristics in telling why they preferred one brand of beans over another.

You've got a lot going for you in the bean business. Your products have consumer acceptance--they're well liked. They offer convenience, an important ingredient for success, and many of the newer approaches to processing beans offer the possibility of convenience with a margin for creativity. They're economical, although this is a factor that seems to rank rather far down on the totem pole. And they're nutritious, an advantage that has not been fully explained or exploited.

THE WORLD FOOD DOLLAR - AND THE FIGHT FOR IT

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Originally, I was assigned a topic dealing with export markets for dry beans. However, I would rather discuss a broader subject. Dr. Altschul's remarks about protein foods--new foods for developing countries and changing food habits--are particularly interesting. I have had personal experience in introducing wheat foods into the traditional rice-eating areas of South India and East Pakistan. We are now engaged in introducing grain sorghum as a food grain in India, because of our limited supplies of wheat. Here we are finding that indigenous uses in nearby areas are more applicable than are equally unfamiliar American ideas of what will be acceptable.

Mrs. Morley, who has also preceded me on this program, spoke--rather apologetically--about the consumer. Let me hasten to add that there is no need to apologize. We are all consumers, and as Secretary Freeman recently stated to the New York City Council--who, along with others, is also investigating food costs--the American farmer is aware of food prices because he, like the rest of us, buys most of his food at the supermarkets.

You who are in the bean business are of course in the food business. We are living in interesting times with respect to public attitudes towards food. Prominent news coverage is being given to the various groups who are examining U.S. public food policies. For years the dominant factor seemed to be surpluses--but in recent months we have seen a change. Basically, I believe that the United States has had a policy of cheap food. In terms of relative purchasing power, our food is a bargain compared with the situation abroad. We also have a heritage of helping the less fortunate. All of these factors are being examined as we enter a new era with respect to public food policies. These are and will be interesting times.

And, now for a broader view. Two basic conditions in the world today have made agricultural exports big business--economically and politically: (a) Affluence--in Western Europe and Japan --a condition that is spreading from Europe to the Middle East and from Japan to other parts of Asia. People have more money and want to eat better. (b) Population pressures on food supplies in the less developed countries--India, Pakistan, parts of Africa, and South America.

Just how big is the agricultural export market? U.S. agricultural exports in 1965-66 reached a new record of $6.7 billion. This is up $600 million over last year's record. Cash exports were up $700 million while P.L. 480 exports were down $100 million. These exports represent about one-fifth of the total U.S. exports.

In the "Billion Collar Club" we find: (a) Wheat and wheat products--at $1.4 billion. These exports run one-third commercial and two-thirds under P.L. 480. The total value is up $160 million this past year. (b) Feed grains exports were valued at $1.35 billion, up $410 million and about 90 percent for cash. (c) Soybeans and products--at $1+ billion nearly all cash sales. Last year (1964-65) with exports valued at $6.1 billion, we spent $13.4 million in market development--less than 1/4 of 1 percent of the total value.

We carry on cooperation programs, such as the National Dry Bean Council; market surveys, such as Mrs. Morley mentioned; consumer promotion; technical assistance; market intelligence: Info + analyses + market sense = Intelligence; and exchange of teams. We conduct trade fairs: Munich in September--in which Michigan beans will be represented. Our trade fairs are taking on more of a <u>hard sell</u> approach. In trade centers (London, Milan, and Tokyo), we specialize in exhibits and seminary--often concentrating on a <u>phase</u> of one commodity. In store promotions we include food shows--American "weeks" in department stores and supermarkets.

A 2-year study of what other countries are doing reveals some interesting things. First, which are the major agricultural exporters that have promotion programs? Our survey reveals the following countries: Australia, Canada, Denmark, Israel, Netherlands, New Zealand, and South Africa.

An examination of these countries' programs reveals the following general characteristics: (a) Agricultural exports represent a high percentage of their total exports--50 percent or more. Their balance of payments depends heavily on agriculture. (b) Agricultural exports represent a large share of these nations' agriculture. Canadian and Australian wheat; Danish pork, butter, and cheese; Israeli fruits, and vegetables; and New Zealand and Australian wool, lamb, and beef. High percentages of these commodities must find export markets--so they get proper attention. (c) Exports are made, "handles," or coordinated by "commodity" boards, which are quasi-governmental, often have single export control and monopolies. (d) Financing of market promotion is a combination of national government funds and funds from trade and producers, the latter often through a compulsory check-off system. With respect to financing, these efforts are

somewhat similar to the Department's Cooperative Market Development Program, wherein both Government and trade resources are employed. (e) These countries are spending proportionately more than the United States--in some cases total expenditures exceed those of the U.S. Australia spends 20 million for 2.2 billion in value of exports, or nearly 1 percent. Denmark spends 10 million for a billion in exports, or 1 percent. New Zealand spends 11 million for 953 million, or 1.16 percent. Israel spends 1.7 million to promote 124 million in sales, or 1.37 percent. The U.S. spends 12 to 13 million for 6+ billion in sales, or 1/5 percent. In all, these 7 countries have agricultural exports valued at $8 billion--about 2 million dollars more than U.S. They spend $53 million, or four times what we spend.

These countries do much the same as we do, although they tend to concentrate on: (a) In-store promotion; (b) incentives to entice merchandisers to push their commodities; (c) in National Food Weeks--Australian, New Zealand, etc.; (d) in slogans, such as: "If its Danish - It's Good," "Fresh from Holland," "Cream and Sunshine - New Zealand Butter," "Australian Sunshine Foods;" (e) in centralized or specialized export brands, such as: "Jaffa" brand (Israel), "Kangaroo Butter" (Australia), "Anchor and Fern Leaf" (New Zealand). These things are being done by countries that market largely through government monopolies. They can and do set prices; can and do sign long-term contracts at fixed prices and on credit terms. Why, then, do they also promote? Is not price the sole factor? These countries represent formidable competition--they know they are dependent on exports and they are aggressive.

What does this mean to us as members of the U.S. agricultural community? Is 20 percent of our total exports important? Is the output of 1 acre in 4 important? True, we are proportionately not as dependent as our competitors are on exports but remember that we are talking about nearly 7 billion dollars in foreign trade.

Fortunately, our foreign market development program has been adequately funded by the government. This program is based on a cooperative principle, wherein both contribute. The greatest void we have is in imaginative ideas and aggressive, well-planned campaigns from well-organized industry groups.

We have too much of what I call "Rainy Day Programs." Years ago when I was a high school teacher in the Health and Physical Education classes, the common practice was to hold "Health" classes when it rained. Hence, it was called the "Rainy Day" program. In some of our market development programs--and this could apply to beans--we get occasional flurries of interest, when there are lots of beans or when it rains. These approaches don't make lasting impressions on markets.

NEW QUICK-COOKING DRY LIMA BEANS

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Legumes are a primary source of dietary protein in many areas of the world. Although the cost per unit of legume protein is only a small fraction of the cost of animal protein, the per capita consumption of dry beans in the United States is low and declining. Use of lima and other dry beans is believed to be declining because of a trend toward more convenient foods. Commercial availability of quick-cooking dry bean products may stimulate increased utilization of these low cost, high-protein foods.

A process has been developed for preparing quick-cooking large dry lima beans. It consists of: (1) Intermittent vacuum treatment (Hydravac process) for 30 to 60 minutes in a solution of inorganic salts; (2) soaking for 6 hours in the same salt solution; (3) rinsing; and (4) drying. The process has been adapted to the preparation of other quick-cooking legumes such as small white, pinto, kidney and other common beans, soybeans, and peas.

Vacuum hydration (Hydravac process). Whole dry beans absorb water slowly at ambient temperature. Soaking times of 16 hours or longer are generally required for complete rehydration. Prolonged hydration was considered a limitation to a systematic study of factors affecting cooking characteristics, as well as to any process for preparing quick-cooking beans. Hydration at elevated temperatures facilitated water imbibition; but under certain conditions it has unfavorable effects on the appearance of the dried product and the texture of the rehydrated, cooked product.

The Hydravac process facilitates infusion of salt solution through the hilum and fissures in the hydrophobic outer layer of the seedcoat. Wetted by the solution, the inner membrane hydrates rapidly, plasticizing the seedcoat and causing it to expand to its maximum dimensions within a few minutes.

Beans are hydrated generally at ambient temperature (70° to 75°F.). The vacuum is drawn and released intermittently at 5 minute intervals for 60 minutes. After release of the final vacuum, cotyledons float freely within the seedcoat and are bathed uniformly with hydration medium. Although the cotyledons expand to fill the seedcoat within 2 hours, lima beans are generally allowed to soak

for about 6 hr. (table 1). Other, more refractory legumes are hydrated and soaked for longer periods at ambient or elevated temperatures. Hydration, as judged by plump appearance of the beans, was accomplished in less than 20 percent of the time required normally, and the number of "fish-mouth" and "butterfly" beans was minimized in the final product, with the result that less disintegration of beans occurred during cooking.

TABLE 1.--Effect of soaking time on subjective cooking time of large, dry lima beans[1]

Soaking time (hr.)	Subjective cooking time (min.)
3.5	[2]43
4.5	33
5.5	30
8.0	29
16.0	28

[1]Hydrated in standard medium at 70°F.
[2]Nonuniform texture.

Hydration media. It is recognized generally that fresh, green beans and peas cook more rapidly than their more mature, field-dried counterparts, and that old, less viable beans require longer cooking. It appeared reasonable to presume that legume proteins influence texture and cooking characteristics of cotyledons. Consistent differences were observed on polyacrylamide gel electrophoretograms of proteins extracted from immature green, field-dried mature and mature, dry-aged lima beans. On the basis of these observations, hydration media were designed to disperse or solubilize proteinaceous material. Mixtures of alkali carbonates provided a slightly alkaline buffer solution. Metal chelating agents, such as the phosphates, were added to aid in disassociating possible calcium or other metal salt-protein complexes and to prevent discoloration. With these exceptions, the development of hydration media progressed on an empirical basis. The most generally useful hydration medium contained the following ingredients: 2.5 percent sodium chloride; 1.0 percent sodium tripolyphosphate; 0.75 percent sodium bicarbonate, and 0.25 percent sodium carbonate.

Sodium chloride decreased the cooking time for seedcoats and increased slightly the cooking time for cotyledons (table 2). Beans hydrated overnight in the conventional manner in a 1-percent solution of sodium chloride and cooked in a fresh solution of the same composition were uniformly cooked within 35 minutes and compared favorably with fully processed, quick-cooking dry lima beans. In addition, the sodium chloride intensified and improved

the natural bean flavor. However, sodium chloride had an adverse effect on the flavor of lima beans that were quick-soaked and cooked in the soak solution (table 3).

TABLE 2.--Effects of sodium chloride on cooking rate of untreated large dry lima beans

	Cooking time, in:			
	Distilled water		1-percent sodium chloride	
Hydration medium	Seedcoat	Cotyledon	Seedcoat	Cotyledon
	Min.	Min.	Min.	Min.
None (dry beans)	80	60	70	65
Distilled water[1]	100	32	55	33
1-percent sodium chloride[1]	50	32	35	30

[1]Hydrated 16 hr. at 70°F.

Sodium tripolyphosphate, a good chelating agent for calcium, improved cooking time and texture of cotyledons and prevented possible discoloration due to contact with metals such as copper and iron during processing.

The tenderizing effects of sodium bicarbonate are illustrated in table 4. These effects may be related to the influence of this salt on the pH of the hydration medium (table 5).

Increasing the total concentration of mixed salts was not advantageous. Lower salt levels caused mottling of seedcoats and increased the cooking time of processed dry beans.

Effects of temperature and time on bean hydration. The hydration and soaking time required to attain a given cooking time, or the cooking time obtained after a fixed hydration and soaking period, decrease with increasing temperature of the hydration medium up to temperatures of about 125°F. At ambient temperature, lima beans hydrate more rapidly than most other dry beans except lentils. Compared with common beans, which require up to 24 hours for complete and uniform treatment at ambient temperature, large lima beans require only about 6 hours. Hydration and soaking at elevated temperatures are particularly effective in reducing processing time for the common white beans and reducing total processing time to about 6 hours at 122°F. At the same temperature, pinto beans may develop a purple-brown color during hydration, which is accentuated during drying. At ambient temperature both dry and cooked pinto beans require treatment for 16 hours but retain a natural, attractive color and appearance.

Drying. Threshing, cleaning, and handling low-moisture dry beans result in excessive cracking of seedcoats. During processing

TABLE 3.--Effects of sodium chloride on cooking and other characteristics of large dry lima beans

Hydration, medium and method[1]	Cooking medium	Subjective cooking time, flavor and texture when cooked in: Distilled water				1-percent sodium chloride			
		Seed-coat	Coty-ledon	Flavor	Texture	Seed-coat	Coty-ledon	Flavor	Texture
		Min.	Min.			Min.	Min.		
Distilled water:									
A	Original	80	60	Flat	Granular	70	65	Satisfactory	Poor
B	Soak	53	52	Poor	Satisfactory	[2]46	[2]54	Poor	Satisfactory
B	Fresh	61	42	Flat	Variable	37	39	Satisfactory	Do--
C	Do--	100	32	Do--	Granular	55	33	Do--	Do--
1-percent sodium chloride:									
B	Soak	--	--	--	--	55	53	Poor	Satisfactory
B	Fresh	34	50	Poor	Variable	35	60	Do--	Variable
C	Do--	50	32	Satisfactory	Satisfactory	35	30	Satisfactory	Satisfactory

[1]Method--A - cooked in boiling solution without prehydration; B - heated in boiling solution 2 minutes and steeped 1 hour in hot solution; C - soaked at ambient (70°F.) temperature for 16 hours.

[2]Salt added after soaking.

TABLE 4.--Effect of sodium bicarbonate in hydration medium on cooking time of processed lima beans

Sodium bicarbonate in hydration medium	Subjective cooking time
Percent	Min.
0.25	36
.50	35
.75	28
1.00	27

TABLE 5.--Effects of pH of hydration medium on characteristics of quick-cooking large dry lima beans

pH				
Hydration medium		Cooking water	Subjective cooking time	Characteristics
Initial[1]	After soak			
			Min.	
6.2	6.7	6.5	41	Best cooked appearance.
8.0	7.2	7.0	38	Good flavor and appearance.
9.0	8.0	7.1	37	Optimum.
9.5	8.9	7.5	37	Strong flavor.
10.5	9.6	8.3	33	Mottled, dark, and unacceptable.

[1]Standard formulation adjusted with sodium carbonate or hydrochloric acid.

these fissures may be extended, destroying the integrity of the seedcoat. Drying processed beans under a high velocity, hot air stream weakens seedcoats, producing unattractive, split "fish-mouth" or "butterflylike" beans. These conditions are minimized by the Hydravac process and drying the beans isothermally under a low velocity air stream (30 f.p.m. or lower) at temperatures not exceeding 140°F. for 24 hours or higher temperatures up to 170°F. for 8 hours or less (table 6).

Process Adaptability. Different lots of untreated lima beans varied widely in their cooking characteristics. This variability was minimized when they were converted to quick-cooking products (table 7). Since cooking time may be regulated by adjusting the composition of the hydration medium, soaking time and temperature, more uniform processed products may be produced. The cooking properties of several varieties of untreated and processed dry legumes are summarized in table 8. The hydration medium and soaking times employed were not

necessarily optimal for each variety. However, all varieties processed satisfactorily by using the hydration medium designed primarily for processing lima beans. It may be seen that significant reductions in cooking time were achieved exclusive of the time required to hydrate beans prior to cooking. Processed soybeans required 70 percent less cooking time than untreated, presoaked beans, and had a mild pleasant flavor.

TABLE 6.--Effects of drying temperature on cooking characteristics and quality of quick-cooking lima beans[1]

Drying temperature	Moisture content	Subjective cooking time	Shear-press F_c values[2]	Comment
°F.	Percent	Min.	Pound	
130	10.2	32	26	Good flavor and appearance.
140	7.5	39	29	Acceptable.
150	6.2	42	30	Slightly dark, burned flavor.
160	5.2	41	31	Dark color, burned flavor.
170	4.2	36	32	Very dark, burned flavor.

[1]Dried 24 hours.

[2]Cooked 30 minutes in distilled water.

TABLE 7.--Comparison of standard and quick-cooking lima beans

Lot	Subjective cooking time: Standard[1] Seedcoat	Standard[1] Cotyledon	Quick-cooking Whole dry bean
	Min.	Min.	Min.
A	80	27	25
B[2]	70	39	27
C	65	38	30

[1]Rehydrated 16 hours in distilled water at 70°F.

[2]White seedcoat variety, South Coast Field Station, Irvine, California.

Stability of processed lima beans. The influences of moisture content and storage temperature on the quality of quick-cooking dry lima beans are shown in table 9.

Initially, the subjective cooking times were inversely proportional to moisture content. After storage for 3 months at 38° and 70°F., small but nearly identical increases in cooking time were observed. At 100°F., increases in cooking time were

TABLE 8.--Subjective cooking times of various standard and quick-cooking dry legumes

Legume	Subjective cooking time in distilled water		
	Standard[1]		Quick-cooking[2]
	Seedcoat	Cotyledon	Whole dry seed
	Min.	Min.	Min.
Lentil	20	30	13 (6)
Lima, large	80	27	25 (6)
Lima, baby	65	35	25 (6)
Pinto	50	35	30 (6)
Peas, whole green	50	75	35 (18)
Red kidney	75	45	35 (24)
Red	55	40	35 (24)
Pink	65	40	35 (24)
California small white	80	30	35 (6)
Great Northern	55	40	35 (18)
Blackeye	40	45	45 (18)
Soy	< 150 (est.)	180	50 (24)

[1]Prehydrated 16 hours in distilled water at 70°F.
[2]Figures in parentheses indicate soaking times (hr.) in hydration medium at 70°F.

TABLE 9.--Effects of storage on quick-cooking lima beans[1]

Storage		Subjective cooking time		
Temperature	Time	Moisture content of beans		
		5.7 pct.	8.0 pct.	12.0 pct.
°F.	Month	Min.	Min.	Min.
	0	41	36	31
38	3	45	41	35
38	11	52	41	41
70	3	46	41	37
70	11	53	45	58
100	3	61	80	115
100	11	70	110	140

[1]Stored in the dark. Hydration medium contained 0.25 percent sodium bicarbonate instead of 0.75 percent.

directly proportional to bean moisture content. These changes were accompanied by browning and the development of off-flavors and off-odors. At 8.0 percent moisture, beans exhibited nominal quality changes during storage at 70°F. At both higher and lower moisture levels, cooking times increased more than 75 percent at the samé storage temperature. At ambient temperature, processed beans appear to have an optimum moisture range above and below which they deteriorate at a more rapid rate.

TABLE 10.--Nutritional value of proteins in quick-cooking and untreated lima beans[1]

Sample	Protein efficiency ratio[2]
Normal, raw, dry	0.00
Quick-cooking, raw, dry	.00
Normal, cooked, freeze-dried	1.83
Quick-cooking, cooked, freeze-fried	1.91
Casein, control	2.50

[1]Booth, A. N., private communication, November 1965.
[2]Expressed as weight gain per gram of protein ingested by weanling rats during 28-day feeding period.

In general, quick-cooking lima beans were most stable when stored under refrigeration. However, only nominal changes in cooking time and appearance occurred when beans containing 8.5 to 9.5 percent moisture were held at ambient temperature for up to 6 months.

Nutritional value of quick-cooking lima bean protein. Processed lima beans were cooked in boiling distilled water, drained, and freeze-dried. Untreated raw beans from the same lot were hydrated over night and cooked in distilled water, drained, and freeze-dried. The two samples of freeze-dried beans and samples of the same lots of uncooked, untreated, and raw quick-cooking beans were evaluated for their protein efficiency ratio (PER). The results of this study are presented in table 10. The PER values for the cooked untreated and the cooked processed beans were nearly identical, indicating that processing did not impair the nutritional value of lima bean protein.

DRUM AND SPRAY DRYING AND CHARACTERISTICS OF PRECOOKED BEAN POWDERS[1]

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Whole precooked dry pea beans were successfully dried to instant precooked bean powder on a single- and on a double-drum dryer. Continuous production was achieved without the use of chemical additives to establish or maintain a continuous sheet. The single-drum dryer with applicator rolls had a capacity of 6.64 pounds of solids per hour per square foot of drum surface at a sheet moisture content of 5.2 percent and a sheet density of 2.16 pounds per 100 square feet. The capacities obtainable with the double-drum dryer were about the same as those with the single-drum dryer; however, sheet densities were considerably lower for the single-drum dryer.

Mashed bean puree could be dried only on the single-drum dryer because of gelatinization of the puree in the trough of the double-drum dryer. Infrared lamps had to be installed on the double-drum dryer to obtain a final moisture content of 5.0 percent.

Pureed cooked beans were successfully spray-dried in a vertical co-current spray-drier. The effect of puree solid content, drying temperature, type of nozzle, and nozzle pressure were determined. Homogenizing the bean slurry prior to spray-drying resulted in a powder containing an excessive amount of free starch. An acceptable 3.0-percent moisture powder was obtained from 20-percent solid content nonhomogenized bean puree by using a No. 56 nozzle with No. 20 core operating at 2,500 p.s.i. and a drying air outlet temperature of 180 to 190°F.

Drum- and spray-dried bean powders were analyzed for flavor, reconstitution, color, bulk density, percent free starch, and solubility index. The reconstitution of spray-dried powders was somewhat better than that of drum-dried powders; however, a taste

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[1] The work described is part of a cooperative research project between the Western Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture, Albany, Calif., and the Departments of Agricultural Engineering and Food Science, Michigan State University, East Lansing, Mich.

panel could not detect any difference between the two. Retort-cooked powders reconstituted better and were favored by a taste panel over atmosphere-cooked powders.

DRUM DRYING

Pea (navy) beans are an important crop in Michigan. Although they are one of the best plant protein sources available, the domestic per capita consumption has recently declined. This decrease is mainly caused by the long time required for preparation--soaking and cooking.

Instant precooked bean powders will eliminate the soaking and cooking requirements. An investigation was started 2 years ago on ways of manufacturing the bean powder. Substantial interest has already been shown by the bean producers, as well as by some possible users of the powder, such as soup manufacturers and United Nations agencies.

In making an instant bean powder, dry pea beans are soaked, cooked, conditioned for drying, dried, crushed or milled, and packaged. This section is concerned with the drum drying. Drum- and spray-drying are the most economical methods for the removal of excess moisture from low solid content foods.[2] Both processes have been used successfully in this study to dry cooked pea beans in one drying operation to a 5-percent moisture, rapidly rehydrating powder. The main requirement is that the powder must reconstitute rapidly to the same texture, appearance and taste of a conventionally prepared bean soup. Only powders in which cell rupture has been kept to a minimum will meet this requirement. If too many cells are broken and too much free starch is liberated, the reconstituted product will be pasty and unacceptable. For this reason instant bean powder cannot be made by dry milling whole precooked dry beans.

Drum dryers are contact dryers. The heat required for evaporation of moisture is supplied by an internally heated revolving drum. The drying product is usually fluid or semifluid and is deposited in a thin layer on the surface of the drum. The product is carried along with the rotating drum and is removed as a dry sheet by a "doctor" knife or blade. Two types of drum dryers are in use in the food industry, the single- and the double-drum dryer.

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[2]Anonymous. Higher quality drying at lower cost. Food Processing 26(1): 92, 1965.

The single-drum dryer has been successfully applied in the potato flake industry.[3] The potato mash is applied to the single steam-heated drum by applicator rolls; as many as five applicator rolls are used. Potato flakes produced on a single-drum dryer have a higher bulk density than flakes produced on a double-drum dryer.[4] The double-drum dryer is very suitable for making precooked dehydrated sweet potato flakes.[5] This type consists of two steam-heated drums rotating towards each other from the top. The feed material is fed into the V-shaped trough formed by the two drums. Material immediately adjacent to the drum adheres to the heated surface as a thin film and is carried around to the doctor knives which remove the film in the form of a dry sheet. Four main variables that influence the operation of a drum dryer are the steam pressure, the revolutions per minute, the film thickness, and the moisture content of the feed material. Other minor factors that may affect the dryer output, such as ambient temperature and humidity, puree temperature and viscosity, and puree level in the trough are not considered here.

Experimental. The results reported here were obtained with pea beans bought in bulk at an elevator. The beans were stored at 40°F. for varying lengths of time.

In a series of soaking and cooking tests, a taste panel preferred bean powder made from beans soaked at 210° for 40 minutes and cooked at 250°F. for 90 minutes over beans soaked and cooked at different temperatures and times. Except for some tests with atmospheric-cooked beans, all beans were soaked and cooked under the above-stated conditions. The methods of cooking and soaking are important because they affect the adherence of beans to drums, as well as color and taste of the final product.

A Langsenkamp pulper was used to puree the whole cooked beans (moisture content 55 percent) through a 0.094-inch screen. During the pureeing, moisture content was adjusted to the level desired for a particular test. It is not necessary to preserve the flake form with beans. A Fitzpatrick sharp-knife hammermill

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[3]J. G. Moore and O. C. Samuel. Advances in drum drying process. Food Processing 25(7): 58, 1964.

[4]R. H. Eskew and F. H. Drazga. Potato flakelets - A new dense product from flakes. Food Technol. 16(4): 99, 1962.

[5]H. J. Deobald, T. A. McLemore, V. H. McFarlane, M. T. Roby, D. R. Peryam, and F. Heiligman. Precooked dehydrated sweet potato flakes. U.S. Dept. Agr., Agr. Res. Service, ARS 72-23, 1962. J. I. Wadsworth, S. P. Koltun, A. S. Gallo, G. M. Ziegler, and J. J. Spadaro. Instant sweet potato flakes: Factors affecting drying rate on double-drum dryer. Food Technol. 20(6): 111, 1966.

with a 0.027-inch screen was used to grind the bean sheet. The powders were evaluated as soup; the ratio of water to bean solids was 4.50:1.

A single- and a double-drum dryer were used for this work. The double-drum dryer was a Bufflovak Atmospheric Laboratory model equipped with 6-inch x 7-5/8-inch chrome-plated drums and a variable speed drive. Stainless steel guide-shields were added to both drums to guide the dried product away from the drum and to shield the product from steam. An agitator was installed between the drums to distribute puree evenly. The agitator traveled back and forth between drums and was made of two steel blades each 1/16 inch in thickness and 1/2 inch in width. The back-and-forth motion was achieved by an electric motor that drove a pivot arm through a variable-speed reduction gear box. The proper speed of the agitator was important.

The single-drum dryer consisted of the double-drum dryer with several modifications. When single-drum drying was required, a pair of nonheated applicator rolls were installed above the heated drums in such a way that an applicator roll was above each heated drum. This, in effect, made two single-drum dryers, each one with one applicator roll. The unheated applicator rolls were driven at the same peripheral speed as the heated drums through roller chain and sprockets connected to the original dryer drive mechanism. The clearance between the applicator roll and the heated drum was 0.033 inch. To achieve several applications or layers of puree, as is done with an industrial single-drum dryer, the doctor knife was lifted for a predetermined number of drum revolutions. Each revolution of the heated drum increased the number of applications or layers of puree by one and thereby simulated the effect of one applicator roll. When the desired number of product applications had been made, the doctor knife was lowered for one revolution of the heated drum and the dried product removed.

The raising and lowering of the doctor blade were automatically accomplished by an electronically operated device which counted the number of revolutions of the heated drum. The device actuated an air cylinder which in turn, lowered the doctor blade for one complete revolution of the heated drum. After one revolution, the dried sheet had been removed, and the knife again automatically raised. The dryer operator could control the number of product layers by presetting the automatic knife-lifting device. The knife-lifting control consisted of three solenoids, several microswitches, one relay, and a ratchet wheel system.

The results obtained with the laboratory single-drum dryer cannot be directly applied to an industrial single-drum dryer with applicator rolls. Although the retention time of the dry sheet on

a large single-drum dryer with five applicator rolls turning at 3 r.p.m. is the same as that of the sheet of a laboratory model applying five layers (the knives are lifted four times) and turning at 15 r.p.m., the times that the consecutive layers are held on the drum are different. Still, the authors believe that the drying characteristics of the two dryers are almost analogous.

Infrared heat lamps were installed above the stainless steel guide-shields of the double-drum dryer as a final drying procedure. The lamps were 375 watts each and could be individually controlled as to their "on-off" position and their orientation related to the sheet of product coming off the drums. They were generally used at a distance of 4 inches above the product coming off the drums. At this setting, the lamps removed 2 1/2 to 4 percent of moisture, depending on drum speed. The cost was about 0.05 cent per pound of dried product produced. The lamps were not needed on the single-drum dryer because it was possible to decrease the final product moisture content on this dryer in one operation to 50 percent, the maximum value allowed for satisfactory shelf life of the product.[6]

Results and discussion. The variable that affected drying characteristics most was the physical state of the beans when placed on the heated drums. For this reason the drying characteristics of pureed and non-pureed material will be discussed separately.

Pureed bean mash with moisture between 65 and 90 percent was dried on the single- as well as on the double-drum dryer at steam pressures and revolutions per minute values between 15 and 90 p.s.i.g. and 2 and 25, respectively. On the single-drum dryer a satisfactory sheet was obtained with puree moisture contents between 65 and 70 percent and steam pressures between 20 and 50 p.s.i.g. An applicator roll was not effective at puree moisture contents above 70 percent because of the low viscosity of the slurry.

With 65-percent-moisture bean puree on the single-drum dryer, increasing the drum speed resulted in higher production rates. The increased dryer outputs caused higher final moisture contents of the dried sheet. The maximum production rate (3.57 lb. of solids per hour per square foot of drum surface at a moisture content of 4.5 percent) was obtained at 50 p.s.i.g. steam and 17 r.p.m. The sheet consisted of five layers. Its density was 1.20 lb. of solids per 100 square feet. Puree with a moisture content of 70 percent could also be dried on the

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[6] M. M. Boggs, H. J. Morris, and D. W. Venstrom. Stability studies with cooked legume powders. Food Technol. 18(10): 114, 1964.

single-drum dryer. However, the production rates were lower and the moisture contents higher as compared with the 65 percent moisture puree.

The many tests run on the double-drum dryer have shown that this equipment is not suitable for drying pureed beans. At no time was it possible to maintain a continuous product sheet with a moisture content below 10 percent. A satisfactory sheet could sometimes be established for a short period, but after a half hour to an hour, depending on the drum temperature, the sheet would become too wet or would vanish. This behavior was caused by the change in viscosity of the puree in the trough between the drums due to gelatinization of starch. When starch in solution is gelatinized, the molecules swell, thereby increasing the viscosity of the starch solution.

When bean puree was heated in the presence of certain additives, gelatinization was markedly retarded and adherence to the drum improved. The chemicals were added to the puree before the double-drum drying operation and although they retarded gelatinization, it was not eliminated. To keep the drum dryer in continuous operation, periodical removal of the gelatinized puree from the trough was required. For this reason and because of the effect of cost of additives on final value of the powder, it was decided to discontinue the testing of additives for use in bean puree on the double-drum dryer.

Non-pureed cooked beans have an initial moisture content of 55 percent. The beans had to be flattened between two 6-inch steel rollers before they could be applied to the drum. The crushing was necessary to insure pickup of the beans in the trough of the 6-inch x 7 5/8-inch laboratory drum dryer. Probably the crushing operation can be eliminated on industrial-type dryers because of the larger dimensions of the pinch between the drums or the drum and applicator rolls.

As could be expected the output of the single-drum dryer, as well as the final moisture content, increased with an increased number of layers and/or revolutions per minute. At 30 p.s.i.g. the moisture content of the final product with five applicator rolls increased from 4.4 percent at 5 r.p.m. to 5.4 at 9 r.p.m. Increasing the number of layers at this pressure from 3 to 5 changed the dry sheet moisture content from 4.2 to 5.5 percent at 8 r.p.m. A sharp change in sheet density (from 1.65 to 4.35 pounds of solids per 100 square feet) occurred at 30 p.s.i.g. when the number of sheet layers was increased from 3 to 6 at drum speeds between 5 and 9 r.p.m. Increasing the number of applicator rolls seems to be the best way of controlling the sheet density.

Increased steam pressure raised capacities because it allowed the use of higher drum speeds. The highest capacity was obtained at the highest steam pressure at which no burning of the sheet to the drum occurred. This, in general, was true for every type of bean material dried on the single- as well as on the double-drum dryer. For the non-pureed beans on the single-drum dryer, output of about 5.0 percent moisture content bean powder was raised from 3.10 to 5.11 to 6.64 pounds per hour per square foot by increasing the steam pressure from 25 to 50 to 80 p.s.i.g.

The optimum condition obtained with non-pureed material on the single-drum dryer was at a steam pressure of 80 p.s.i.g. at 23 r.p.m. using 5 layers. The dryer output under those conditions was 6.64 pounds of solids per hour per square foot at a moisture content of 52 percent and a sheet density of 2.16 pounds of solids per 100 square feet.

Non-pureed crushed beans lend themselves very well to double-drum drying. Beans had to be dried on the double-drum dryer in a relatively narrow steam-pressure range. At pressures above 50 p.s.i.g. the sheet had a tendency to burn on the drums; steam pressures below 20 p.s.i.g. resulted in insufficient drying. The clearance between the drums was rather critical. A spacing of 0.008 inch gave no sheet, only crumbs, while a clearance opening of 0.013 inch gave a wet sheet.

The output rate of the double-drum dryer was affected by the revolution per minute and the clearance setting of the dryer. The final sheet moisture content of experimental tests lay between 5.5 and 8.2 percent if no infrared lamps were employed; with the lamps the moisture contents varied between 2.3 and 5.0 percent. The sheet density of the double-drum-dried bean sheet was found to be between 1.4 and 1.6 pounds of solids per 100 square feet. The maximum production of material with a moisture content below 6.0 percent was obtained on the double-drum dryer without infrared lamps at 6 r.p.m., 45 p.s.i.g. steam pressure, and 0.010 inch clearance. The capacity under those conditions was 4.29 pounds of solids per hour per square foot of surface area. When the infrared energy was employed, the capacity increased to 6.58 pounds of solids at the drum-dryer settings of 10 r.p.m. at 50 p.s.i.g. steam and clearance as above.

Pureed versus non-pureed material. Pureed bean material could be dried successfully only on the single-drum dryer. The solids content of the puree had to be at least 30 percent to prevent gelatinization of the puree. The puree is very viscous at this moisture content and it is more difficult to convey to the drum dryer and to distribute in the trough than is non-pureed

beans. In addition, the pureeing of this high-solids material requires considerable power.

In order to dry 1 pound of 70-percent-moisture bean puree to 5 percent 0.684 pounds of moisture must be evaporated; for whole beans with a moisture content of 55 percent, only 0.426 pounds of moisture must be removed per pound of beans. The amount of moisture to be evaporated from 70 to 55 percent material in order to produce 1 pound of 5-percent moisture content bean powder is 2.16 and 0.90 pounds of water, respectively. This means that about 2,520 B.t.u. are saved per pound of bean powder if 55 rather than 70 percent moisture content material is dried on the drum dryer. This figure would be many times larger if 90 percent-moisture puree were compared with the 55 percent moisture content non-pureed material. It is obvious from an energy as well as a convenience standpoint (one less operation) that non-pureed beans are better suited for drying on single- or double-drum dryers than pureed bean material.

Single- versus double-drum dryer. The capacities that could be obtained on the single- and double-drum dryers were approximately the same. The output rate at least equaled that obtainable when making potato flakes.[7] The double-drum dryer permits certain fixed cost savings per unit of capacity (single motor, single piping, etc.), compared to the single-drum dryers. However, the operating costs will be higher because a secondary drying operating, such as infrared drying, is required to obtain a final moisture content below 5 percent.

The single-drum dryer has the advantages of giving a higher-density sheet and a lower final moisture content. A high sheet density is important if the cooked material is to be marketed in the form of flakes. Another consideration in favor of the single-drum dryer is the fact that there are a considerable number of potato-processing plants now operating with single-drum dryers in this country. Potatoes are often not available during the whole year. These plants can now keep their operations going 12 months a year by making cooked bean powder on their single-drum dryers during the off-season for potatoes.

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[7] J. M. Cording, J. Willard, R. H. Eskew, and J. F. Sullivan, Advances in the dehydration of mashed potatoes by the flake process. Food Technol. 11(4): 236, 1957.

The data presented in this report were obtained on a laboratory-sized single- and double-drum dryer. Although the results may not be directly translatable to large-scale dryers, the principles apply and may form the basis for the design of full-sized drum dryers for the drying of pea bean powder.

SPRAY DRYING

No work has been reported on use of the spray dryer to produce an instant precooked bean powder. Spray dryers are widely accepted in the food industry. They vary widely in type, being classified according to direction of airflow and method of producing atomization of the product to be dried. For example, airflow can be horizontal or vertical and atomization can be achieved by pressure or centrifugal force. The objective of the spray drying experiment was to determine the operating conditions necessary to obtain a precooked bean powder which could be easily reconstituted.

Experimental. Our results were obtained with pea beans soaked at 210°F. for 40 minutes and cooked in a retort for 90 minutes at 250°F. (15 p.s.i.). A Langsenkamp pulper was used to puree the whole cooked beans. The beans were passed through two sieves with 0.065- and 0.023-inch openings. During the pureeing operation, the moisture content was adjusted to whatever moisture level was decided by the addition of a calculated amount of water. The same cooking and wet milling procedure was used to prepare the beans for all spray-drying trials. In addition, representative lots of the bean puree were adjusted to 15 percent solids and homogenized at 2,000-3,000 p.s.i. in a Manton-Gaulin homogenizer.

Drying equipment. The horizontal co-current spray dryer used for the tests was manufactured by the C. E. Rogers Co. of Detroit, Mich., and had an evaporation rate of 300 pounds of water per hour at a 325°F. inlet air temperature. The drying chamber is V-shaped at the bottom and circular at the top. The approximate inside dimensions are: height 11.5 feet, length 18.5 feet, and maximum width 7.5 feet. A baffle plate is located at 13 feet 2-1/2 inches from the front (wet) chamber wall to prevent the dried product from being carried out through the exhaust end. The dryer is provided with a turbo blower that delivers 300 cubic feet of air per minute at 3,420 r.p.m. and 13.2 inches water to the inlet end of the dryer. At the exhaust end of the dryer an exhaust fan operates at 1,790 r.p.m. at 11.5-inch water column and exhausts 4,400 cubic feet of air per minute. The dryer operates under a partial suction draft.

Feeding the bean slurry directly into the spray dryer was accomplished by using a positive pump to maintain a constant supply of puree to the dryer feed pump. This procedure proved

to be satisfactory in producing a bean powder with a moisture content of 5 percent. During the tests, the bottom of the spray-dryer chamber was lined with paper to allow the dried product to be collected, since use of the unloading screw conveyor resulted in too great a loss of the product. The following characteristics of the spray-dried bean powders were studied: Moisture content, particle size, bulk density, rehydration, viscosity, and retention of cellular structure.

Results and discussion. Homogenizing the bean slurry prior to spray drying gave a powder that reconstituted readily, had a relatively high viscosity, and remained in suspension. The viscosity of the rehydrated powder increased as the feed pump pressure increased. Microscopic examination and blue value tests of the powder showed that there was an increase in the amount of broken cells with increased feed pressure and therefore an increase in free starch (table 1). Sensory evaluations of these powders indicated that they could be considered unacceptable for use as instant soup powders because of their pastiness.

TABLE 1.--The effect of homogenizing on the viscosity and percentage of broken cells in spray-dried[1] bean powder

Feed pump pressure	Viscosity, poise[2]	Broken cells
p.s.i.		Percent
500	41.5	41.7
1,000	69.0	52.7
2,000	71.0	54.8
3,000	76.5	59.4
4,000	82.0	73.3

[1]15-percent solids, inlet air temperature 200 to 300°F. outlet temperature 190 to 200°F.; pea bean slurry homogenized at 2,000 to 3,000 p.s.i.

[2]Brookfield viscometer.

In the study of effect of percentage of solids in the puree on moisture content and particle size, it was found that solid contents higher than 25 percent clogged the nozzles. The moisture content and particle size increased as the solids content of the puree was increased. Increasing the outlet temperature had little or no effect on moisture content of the powder. The average particle size and bulk density decreased and the capacity increased as the outlet temperature increased. Increasing the nozzle size resulted in an increase in particle size and bulk density of the powder and the capacity of the dryer. The moisture content of the powders was similar for the three nozzle sizes used. Further studies are being made to determine the optimum nozzle size. Results indicated that a

satisfactory product could be obtained from an 80°F., 20 percent bean puree fed to the spray dryer at 2,000 to 3,000 p.s.i., through a No. 56 nozzle, a No. 20 core, and a dryer outlet temperature of 180° to 190°F.

The bean powder produced by directly feeding the puree into the dryer rehydrated readily. The viscosity, however, was about 50 percent of that obtained for homogenized powder; also, it did not stay in suspension as well as the homogenized powder. Microscopic examination of the powder showed 88 to 92 percent unbroken cells. Sensory evaluation showed no pastiness.

PROPERTIES AND CHARACTERISTICS OF PEA BEAN POWDERS

Various methods of drying have been used to produce a powder from atmosphere- and retort-cooked, pureed, and non-pureed pea beans. These include spray drying, drum drying (double and single), and tray drying. The latter has not been investigated thoroughly and will not be discussed here. The powders produced have been analyzed for flavor, reconstitution, particle size distribution, color, bulk density, percent free starch, and solubility index.

Experimental. Perhaps the most important characteristic of these powders besides flavor was their ability to reconstitute into a desirable soup mixture. Our method of determining this was as follows: Ten grams of powder were added to 100 milliliters of boiling water and agitated for 90 seconds. This mixture was poured into a 100-milliliter graduated cylinder. The number of milliliters of the solid dispersion that had settled in the cylinder was recorded after 5 and 10 minutes.

Color was measured with the Gardner Color Difference meter; and only hue values will be reported here (table 2). The powders were ground in a Fitzpatrick sharp-knife hammermill with a 0.063-inch screen. Particle size distribution of the resulting ground powders was determined with a Tyler Ro-Tap Test Sieve shaker. The sieve dimensions used are shown in table 3. Typical distribution is shown in figure 1.

Bulk density was measured by transferring 50 grams of powder into a 250-milliliter graduated cylinder and the loose volume determined. Then the cylinder was hit with a hand until the powder had stopped settling and the packed volume was recorded. The density in milliliters per gram was determined.

The free-starch content of the powders was determined by two methods. The broken and intact cells of each sample were estimated microscopically. The "blue value" index of each sample

was also determined. Both methods are empirical and give only estimates of the amount of free starch present in each sample. Studies are under way to determine if a correlation exists between the blue value index and acceptability of the powder as determined by a sensory panel. The solubility index of these powders was determined by the ADMI method.

TABLE 2.--Color of pea bean powder as a result of drying and cooking
[Color measured by Gardner Color Difference meter]

Type of cooking method and sieve No.[1]	Cooked material	Speed of drum	Steam pressure in drum	Spacing between drums	Color a/b (hue)
		R.p.m.	P.s.i.g.	Inch	
Atmosphere-cooked:					
No. 1 ---------	Pureed	4	50	0.016	0.24
2 ---------	Whole beans	7.5	25	.008	.23
Retort-cooked:					
No. 3 ---------	Pureed	4	60	.016	.34
4 ---------	Whole beans	0.7	30	([2])	.31

[1]See table 3 for shaker sieve dimensions.
[2]Single drum.

TABLE 3.--Dimensions for shaker sieve

Sieve Test No.	Sieve Mesh No.	Size in: Microns	Size in: Inches
1-----------	30	590	0.0232
2-----------	50	297	.0117
3-----------	70	210	.0083
4-----------	100	149	.0059
5-----------	140	105	.0041
6-----------	200	74	.0029

Results and discussion. Initially these powders were produced with a double-drum drier with steam pressures varying from 15 to 90 p.s.i.g. and 2 to 25 r.p.m. Both atmosphere- and retort-cooked samples were dried by this method. Not all conditions produced a powder that was acceptable for analysis of the type discussed above. The powder that was produced from atmosphere-cooked pureed pea beans was found to be acceptable from the standpoint of reconstitution (table 4). Results from initial flavor tests indicated that this type of powder was inferior to powder produced from retort-cooked pureed pea beans in flavor (table 5). Retort-cooked pea bean powders produced by the double-drum drier were also found to be unacceptable from the standpoint of reconstitution (table 5). Because of the problems involved in drying pea beans with the double-drum system, a single-drum system was used.

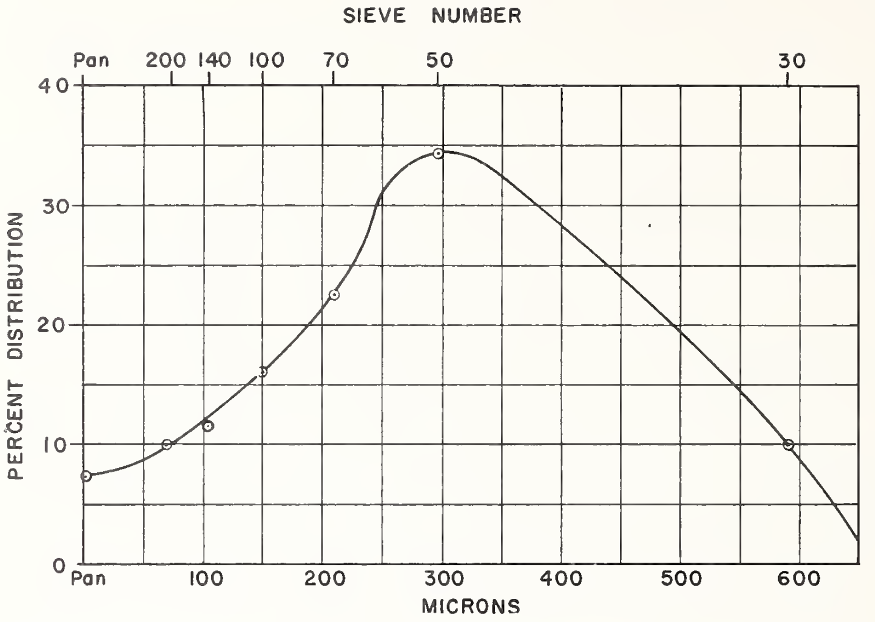

Figure 1.--Particle size distribution of pea bean powders ground through a 0.063-inch screen on the Fitzpatrick hammermill.

TABLE 4.--Reconstitution properties of pea bean powders as a result of drying and cooking methods

Type of cooking method and sieve No.[1]	Cooked material	Speed of drum	Steam pressure in drum	Spacing between drums	Settling after 10 minutes
		R.p.m.	P.s.i.g.	Inch	Milliliters
Atmosphere-cooked:					
No. 1	Pureed	4	50	0.016	46.7
2	Do	4	55	.016	32.0
3	Do	5	50	.016	42.5
4	Do	3	40	.016	48.8
5	Whole beans	7.5	25	.008	16.8
Retort-cooked:					
No. 1	Pureed	4	60	.016, .060	34.0
2	Do	3.5	60	.016, .060	27.5
3	Do	4	60	.016, .060	34.5
4	Do	4	60	.016, .045	31.7
5	Whole beans	7	30	([2])	13.3

[1]See table 3 for sieve dimensions.
[2]Single drum.

TABLE 5.--Flavor and texture evaluations based on a 9-point scale

Treatment	Mean Flavor	Mean Texture
1. Soak 210°F. for 40 minutes and cook for 90 minutes at 250°F.	6.15	--
2. Soak and cook for 3 hours at 210°F.	4.38	--
1. Retort cooked, pureed, drum-dried	5.96	6.13
2. Retort cooked, pureed, spray-dried	5.13	5.58
3. Retort cooked, pureed, homogenized and spray-dried	5.29	5.00
1. Retorted drum-dried sample	5.88	5.35
2. Retorted pureed drum-dried sample	6.06	5.77

The powders produced by the single-drum system reconstitute fairly well as compared to powders produced by the double-drum system. Flavor-panel tests showed no preference between the two types of drying (table 5). The powder produced by the single-drum system was much denser (table 7); the color (table 2) and the solubility index (table 6) were not affected.

Characteristics of the powders. The reconstitution of drum-dried powders is not so good as that of spray-dried powders. Retort-cooked, spray-dried powders settle out at the rate of about 5 to 7 ml. in 10 minutes, as compared to about 10 ml. for single-drum-dried powders and about 30 to 40 ml. for double-drum-dried.

TABLE 6.--Solubility index of pea bean powders as determined by the ADMI method

Type of cooking method and sieve No.[1]	Cooked material	Speed of drum	Steam pressure in drum	Spacing between drums	Reading
		R.p.m.	P.s.i.g.	Inch	Milliliters
Atmosphere-cooked:					
No. 1	Pureed	4	50	0.016	15/40
Retort-cooked:					
No. 2	Do	4	60	.016	15/40
3	Do	4	60	.016	19/40
4	Whole beans	7.5	25	.008	17/40
5	Do	7	30	([2])	18.5/40

[1]See table 3 for sieve dimensions.
[2]Single drum.

All flavor tests were by the hedonic scaling method. Ratings were from "like extremely" to "dislike extremely" on a nine-point scale. Each sample was given to the taster three times. The

results suffered from the error of central tendency. The tasters were not familiar with the product and hence were inclined to give most ratings between 3 and 7. The retort-cooked, drum-dried powders were definitely favored over the atmosphere-cooked, drum-dried powders. The panel had no preference between drum-dried and spray-dried powders but did not like the texture of the homogenized spray-dried sample. This is probably due to a more pasty texture caused by cell rupture and release of free starch during homogenization.

TABLE 7.--Bulk density of pea bean powders

Type of cooking method and sieve No.[1]	Cooked material	Speed of drum	Steam pressure in drum	Spacing between drums	Density loose	Density packed
		R.p.m.	P.s.i.g.	Inch	-- ml./g. --	
Atmosphere-cooked:						
No. 1	Pureed	4	50	0.016	0.60	0.65
2	Do----	4	55	.016	.31	.43
3	Do----	5	50	.016	.50	.60
4	Do----	3	40	.016	.45	.55
5	Whole beans	7.5	25	.008	.50	.64
Retort-cooked:						
No. 1	Pureed	4	60	.016,.060	.38	.49
2	Do----	3.5	60	.016,.060	.40	.50
3	Do----	4	60	.016,.060	.39	.53
4	Do----	4	60	.016,.060	.38	.49
5	Whole beans	7	30	([2])	.53	.69

[1]See table 3 for sieve dimensions.
[2]Single drum.

The color of these powders is of some concern. The normal color of pea beans is white and this is more or less the color obtained from atmosphere-cooked, dried pea bean powder. However, this powder was rejected by the taste panel and furthermore has been up to now extremely difficult to produce. The color of the retort-cooked, drum-dried pea bean powder was light tan or brown (table 2). It is not known which color the consuming public would prefer: the white which they associate with the pea bean, or the brown which they associate with the baked beans. A class of Home Economics students at Michigan State University, when given the choice, preferred the brown color.

The solubility index tests were inconclusive, although there was a slight tendency for an increase in solubility index with improved reconstitution. The particle-size distribution of the ground powder was characterized by the screen size of the Fitzpatrick mill used for grinding. A common particle-size

distribution for the 0.063-inch screen that was used is shown in figure 1. Grinding representative pea bean powder through five different screens was found to have no effect on the reconstitution of the powder. The screens used were 0.063, 0.050, 0.040, 0.031, and 0.027 inches in diameter.

The bulk density of the powder is important from an economic standpoint. The larger the volume the powder occupies loosely (i.e., during the filling of a package), the larger the package required for a given weight of powder. Packed volume is also important since the more the powder settles during transportation the more headspace or empty volume occurs in a package. The bulk density of the retort-cooked, double-drum-dried samples was much less than that of the whole bean, retort-cooked, single-drum dried sample. All samples appear to settle equally after mechanical agitation. The packaging costs of the denser sample will be much less than that of the lighter samples.

The amount of free starch released in powders produced by any drum-drying operation was found to be negligible by both microscopic counting and by the blue index value. None of the samples were found to show any indication of pastiness when evaluated by the sensory panel.

METHODS FOR ACCELERATING THE PROCESSING OF DRY BEANS

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The practice of soaking beans in water has several purposes: (1) To ensure product tenderness and uniform expansion in the can during the thermal process, (2) to increase product yield, and (3) to facilitate cleaning of the beans. Although industrial practices vary considerably depending on such process variables as time, temperature, and water hardness--generally speaking, dry beans must be soaked several hours and overnight soaking is not unusual.

This relatively long soaking time is undesirable to the canner for several reasons. First of all, bacteriological problems may result, particularly during hot weather. Once beans are soaked they should be processed immediately to avoid bacteriological spoilage or other deterioration. A breakdown in the canning line may, therefore, result in substantial losses of product. Secondly, present soaking practices involve extensive equipment and valuable floor space. A short, continuous process would help resolve these

problems, as well as reduce labor cost and increase plant flexibility in changing to different product lines.

The extent of the thermal processing given to most dry bean products like pork and beans results in a sterilizing or F_o value far above the requirements for bacteriological stability. This is because quality factors, such as tenderness and color, are the main determinants of the heat-processing time. Therefore, if these quality factors could be significantly affected during pre-process soaking, less process time and less retort capacity would be required.

In spite of available information on water uptake and on factors that contribute to toughness, practical guidelines to serve commercial processors appear to be lacking. There is no clear understanding of the mechanisms that govern rate of water uptake or of formation of the toughness factor. The investigation reported here attempted to deal with these problems.

Methods and materials. Michigan CHP navy beans ("Jack Rabbit" brand, Michigan Bean Co., Saginaw) of approximately 12- to 15-percent moisture were used throughout this study. The beans were normally stored at room temperature in closed containers prior to treatment. Three methods of forced gas release were used--vacuum treatment, steam pressure treatment, and sonication treatment. Bench-scale experiments were conducted by means of a train composed of the following: a suction flask containing the beans (100 grams), a separate funnel containing soak water connected to the top of the suction flask, a McLeod gage or a mercury manometer, a bleed valve to regulate the vacuum level, and a vacuum pump. The dry beans were exposed to various experimental conditions, and soak water was added before breaking the vacuum. Larger scale experiments using 1,500 grams of beans were conducted in a pilot plant equipped with a steam-jacketed vacuum pan to which soak water could be added while under vacuum. Steam pressure at 15 pounds per square inch (p.s.i.) was applied to beans submerged in water either in a laboratory autoclave (100 g. beans) or in the vacuum pan referred to above (1,500 g. beans). The steam supply was regulated to give a vigorous exhaust while maintaining pressure. Dry beans (15 g.), while submerged in water, were subjected to sonic energy (10 kc. per second) from a magnetostrictive oscillator (Raytheon Manufacturing Company, Model DF-101).

To determine water uptake, beans were drained for 2 minutes and change in weight determined. If the beans were hot, they were first cooled briefly in cold tapwater before draining and weighing. Water uptake was recorded as percent weight increase over initial dry weight. Moisture was determined by standard procedures (A.O.A.C., 1950). In processing studies, weighed amounts of

soaked beans were filled into No. 2 cans, and hot sauce (200°F.) was added to give a final headspace of 1/4 inch. The sauce formula included: 0.114 gallon tomato puree, 0.5 pound sugar, 0.21 pound salt, and water to make 1 gallon. The cans were then sealed and given the desired heat process. Heat penetration data were collected on selected batches to obtain information on the sterilizing value of the processes.

Tenderness. Shear values of the finished product were obtained by a laboratory shear press (Allo Precision, Model SP12). Contents from the processed can were transferred to a sieve and gently moved up and down several times in a water tank. The beans retained on the sieve were drained for 2 minutes and their weight determined. "Calgon"--principally a mixture of sodium tripolyphosphate and tetrapolyphosphate--and food grade sodium chloride were the additives used in this study.

Influence of gas release. When dry beans were submerged in water and then subjected to a vacuum, appreciable amounts of gas were given off. When this vacuum was released, the skin (seedcoat) soon took on a smooth-surfaced, translucent character, which strongly contrasted with the mottled, wrinkled appearance of beans soaked under normal conditions. This suggests that gasses--probably nitrogen, oxygen, and carbon dioxide--fill the interstitial pores and are adsorbed on the internal surfaces of both seedcoat and cotyledons, thus preventing water from migrating into the tissues. It therefore seemed reasonable to assume that water uptake would be enhanced if these gases could be released from the beans, thus allowing more water to enter the pores more rapidly.

Generally, adsorbed and trapped gases can be released by either raising water temperature or reducing the partial pressure of the gases in the surrounding medium. Such was the case here--when the concentration of dissolved gas in the soak water was reduced, rate of water uptake was enhanced (table 1). Maintaining the dissolved gases at saturated concentrations by aeration, on the other hand, gave a negative effect.

TABLE 1.--Effect of degassing of soak water on water uptake (temperature 80°C. soak time 20 minutes)

Treatment	Uptake/100 g. dry bean	Difference from control
	Gram	Gram
Demineralized water (control)	73.4	--
Demineralized water degassed by boiling	78.8	+5.4
Demineralized water degassed by boiling, aerated during soak	70.5	-2.9
Distilled water degassed by boiling	77.5	+4.1

Several practical means are available for reducing amounts of trapped and adsorbed gases: (a) Vacuumization would decrease the partial pressure of gases in the surrounding medium, thereby causing the adsorbed gases to expand and be released. (b) A treatment with steam over the soak water would reduce the partial pressure of noncondensable gases immediately above the soak water and would also reduce the solubility of gases in the uppermost water layer because of the heating effect resulting from condensation. (c) Vibrational energy supplied in a sonication treatment primarily would reduce the amount of trapped gases, but indirectly would also reduce adsorbed gases by accelerating their release into the soak water.

Raw material variables. Large differences in rate of water uptake during the first 20 minutes of conventional soaking (untreated controls) among batches of beans procured at different times were observed in the course of this investigation. Some batches had a water uptake of only 50 percent during 20 minutes, while other batches gained up to 75 percent in weight. Resulting benefits of any particular pretreatment in terms of water uptake beyond that of the controls, therefore, depended greatly on initial quality of the raw material. Variables such as initial moisture content, size, free fatty acids,[1] age, storage conditions and the many factors connected with field production also probably influence water uptake. A study of these, however, lies outside the scope of this investigation.

Treatments to accelerate water uptake. Three different methods designed to affect release of gas were used in these studies: (a) Steam pressure (15 p.s.i.) applied for 2 to 5 minutes, (b) vacuum for about 30 seconds, and (c) sonication for up to 2 minutes (see Methods and Materials).

Typical effects of the various treatments (small scale) are illustrated in figures 1 and 2. All three treatments were shown to accelerate water uptake both at room temperature and at 80°C. However, at 80°C., effects of the treatments were very similar but at room temperature, they were appreciably different.

The temperature of the soak water appeared to play a major role in determining the rates. In experiments in which soak water temperature was varied between 50° and 90°C., maximal uptakes occurred between 60° and 80°C. Therefore, 80°C. was selected as a standard in later experiments, since this temperature tends to minimize microbiological activity and may reduce the processing requirement of the canned product.

[1]H. J. Morris. Cooking qualities of dry beans. Sixth Ann. Dry Bean Conf., U.S. Dept. Agr., Los Angeles, Calif. January 2-4, 1963.

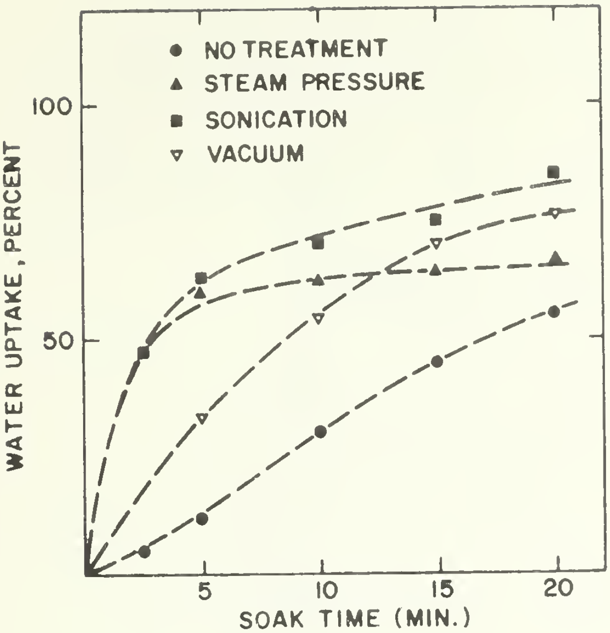

Figure 1.--Effect of various treatments on water uptake at room temperature.

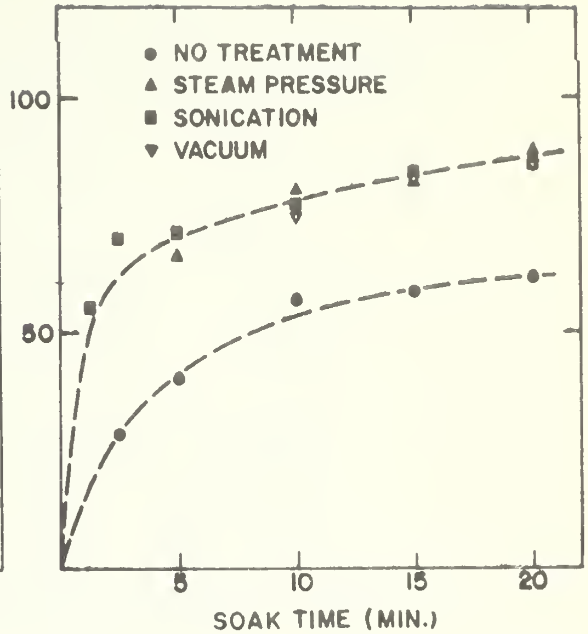

Figure 2.--Effect of various treatments on water uptake at 80°C.

Soaking time was fixed at 20 minutes, which seems to be the maximum time suitable for a continuous process. Also, pea beans are usually considered to be adequately soaked when they reach 53 to 55 percent moisture--the usual maximal level attained from overnight soaking. This level was therefore adopted as a goal to be attained within 20 minutes of soaking.

Results of steam pressure treatment. The importance of gas release during the pressure treatment was illustrated in a series of experiments where parameters of the soaking vessel and amounts of water and beans were varied. Release of gas (and consequently, increase in water uptake) should, in theory, qualitatively benefit by a large free surface area of water, and be counteracted by bean volume. Thus, qualitatively: $WU = C+k A/V_B$, where WU is percent water uptake, C is water uptake in a closed system where gas cannot escape, A is free surface area of the bean/water system, V_B is bean volume, and k a proportionality constant. The expression A/V_B is proportional with 1/N, where N is the number of layers of beans.

The data plotted in this manner (fig. 3) agree with the above expression up to where no further advantage is gained by increasing 1/N (or reducing the number of layers). This point is reached when 1/N equals approximately 0.3 or the equivalent of three layers.

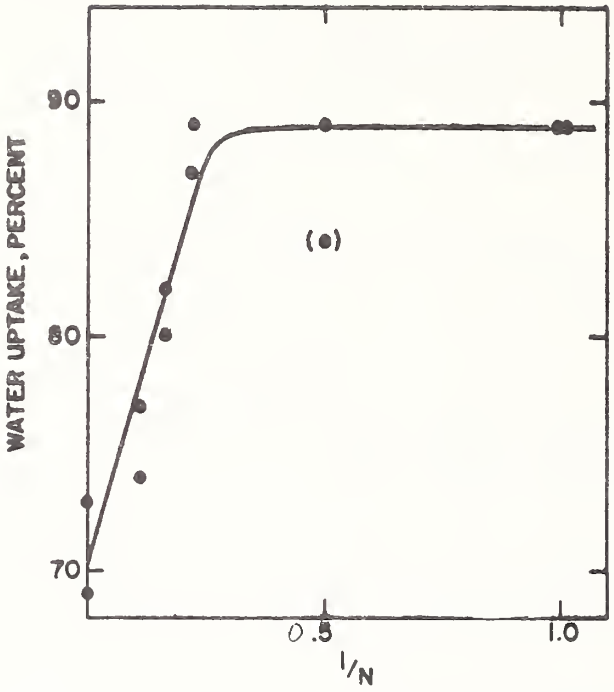

Figure 3.--Effect of bean layer thickness on water uptake.

The same beans undergoing conventional soaking (untreated controls) had a water uptake of only 73 to 74 percent, compared with 89 percent for the pressure-treated beans. The additional water uptake from a steam-pressure treatment thus amounted to 15 to 16 percent. These beans had a moisture content of 55.3 percent and were fully soaked for further processing.

Duration of the steam-pressure process did not seem to be critical beyond a holding time of 2 minutes under pressure. Excessively long holding periods, however, did result in deterioration of bean quality because of overheating. "Come-up" time and rate of pressure release were, to a large degree, determined by the configuration of the equipment, but appeared not to affect water uptake. In these experiments, duration of the various conditions usually were as follows: come-up time, 1/2 minute; holding time, 2 minutes; release of pressure, 2 seconds.

Results of the vacuum treatment. Absolute pressure and time under vacuum are variables in a vacuum treatment. Virtually identical results were obtained when the treatment was conducted at various pressures between 5 and 120 mm. of mercury (fig. 4). This showed that water uptake at low pressure was independent of the absolute pressure in this interval. Extensive time under vacuum seemed to have a slight negative effect on water uptake, while as little as 1/2 minute was sufficient to produce maximal gas release (fig. 5).

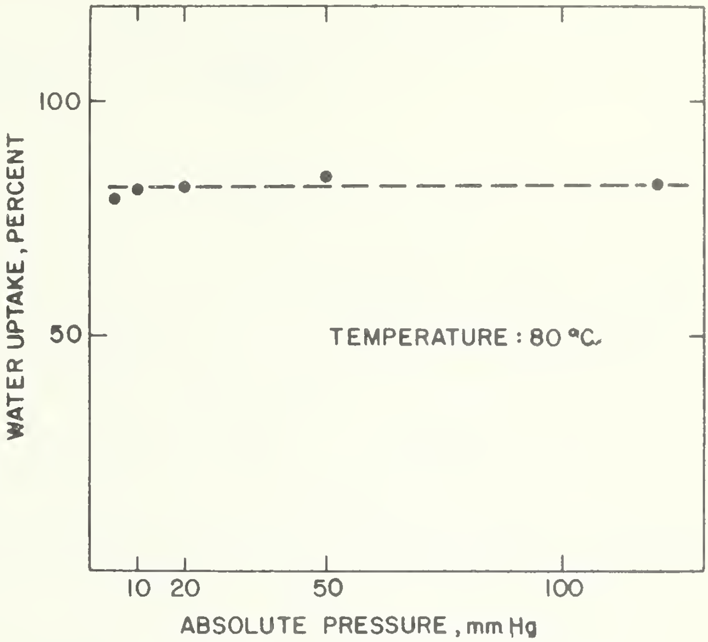

Figure 4.--Effect of vacuum level on water uptake.

Results of the sonication treatment. Owing to limitations of the sonication equipment, it was not possible to establish and to maintain all desirable levels of variables in this treatment. Thus, 80°C. could not be maintained during the entire treatment period because the cooling water supplied to the jacket rapidly decreased the temperature. Despite this, as figures 1 and 2 indicate, sonication may be the more efficient of the three methods. Length of treatment obviously depends on rate of energy input. In our experience, a minimum of 2 minutes was required for maximal water uptake during the 20 minutes of soaking, but this probably could be reduced by using more powerful sonication equipment.

Effect of additives. Various theories concerning the toughness factor in beans have implicated divalent metal ions, pectins, and free-fatty acids. It can be assumed that toughness

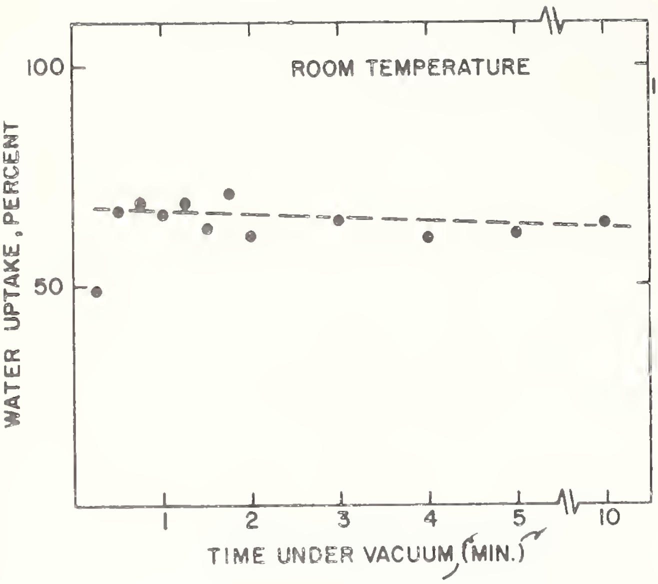

Figure 5.--Effect of time under vacuum on water uptake.

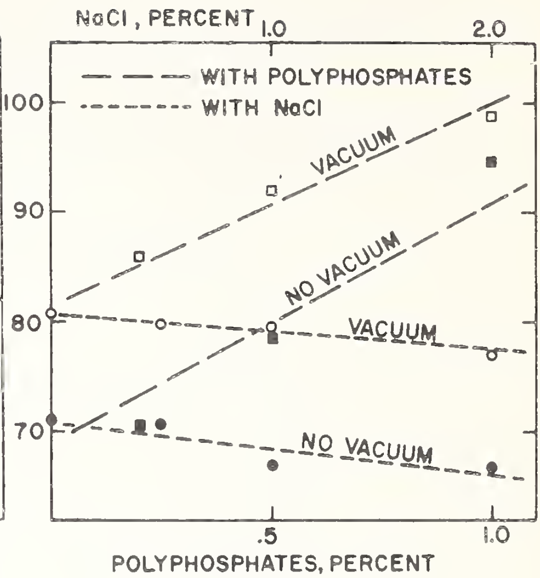

Figure 6.--Effect of additives and vacuum on water uptake.

and water uptake are somehow interrelated since tough beans usually hydrate very slowly (see footnote 1). Therefore, additives that affect the one property can also be expected to affect the other.

Besides the constituents already mentioned, it seems reasonable to include the proteins in a discussion of toughness and water uptake properties, since small amounts of free fatty acids are known to negatively affect water-holding capacity of fish proteins and bring about toughening of frozen fish during storage.[2] Treatment with polyphosphates has alleviated this problem. In fact, polyphosphates are extensively used in the meat industry[3] to improve water-holding capacity of cooked meats. Since these compounds also sequester divalent metal ions, they were used in this study. Bean proteins are of the globulin type; i.e. they require a certain ionic strength to stay solubilized. Therefore, it was expected that salt added to the soak water would render the proteins more soluble and thereby facilitate water uptake and increase tenderness.

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[2]W. J. Dyer and J. R. Dingle. Fish proteins with special reference to freezing. In "Fish as food," G. Borgstrom (ed.), vol. 1, Acad. Press, 1961.

[3]G. D. Wilson. Meat curing. In "The science of meat and meat products," W. F. Freeman and Co., San Francisco, 1960.

The two additives--polyphosphates and sodium chloride--were investigated in small-scale experiments under nonoptimal conditions (fig. 6). Even though maximal uptake was not reached within the alloted 20 minutes, the effects are clearly discernible. The addition of polyphosphates strikingly increased levels of water uptake, while sodium chloride had a slightly depressing effect. However, the higher level of polyphosphates resulted in excessively tender seedcoats and inferior handling quality. In preliminary studies, the disodium salt form of the sequestering agent ethylenediaminetetraacetic acid (EDTA) had no pronounced effects on water uptake. This, therefore, indicated that the swelling noted with polyphosphates was not primarily a result of complex formation with divalent metals, but rather was associated with the known protein-solubilizing properties of these compounds.

Feasibility of a shortened sterilizing cooking period using beans that had undergone accelerated soaking was investigated in an experiment where salt and polyphosphates and combinations of these additives were variables in the soaking process (tables 2 and 3). When salt was added to the soak water, the salt concentration in the sauce was adjusted to give approximately constant salt levels in the finished product. The sauce formula was designed to give a product similar to commercial samples of pork and beans. Commercial samples were evaluated for comparative purposes (table 4).

TABLE 2.--Effect of additives in the saok water on water uptake and characteristics of the finished product (Batch A)

Additive in soak water	Water uptake	Weight gained (processed)	Shear value (processed)
	Percent	Percent	Gram
None	85.0	- 1.7	35.5
None (Control)[1]	84.5	.0	31.8
0.5 percent polyphosphate	99.5	+ 0.7	38.2
0.2 percent polyphosphate	89.7	- 3.8	53.2
1.0 percent NaCl	82.3	- 1.7	33.0
0.5 percent NaCl	81.5	- 4.5	40.0
1.0 percent NaCl + 0.5 percent polyphosphate	98.0	+12.0	17.5
1.0 percent NaCl + 0.2 percent polyphosphate	84.3	+ 2.8	30.5
0.5 percent NaCl + 0.5 percent polyphosphate	102.0	+10.0	21.2
0.5 percent NaCl + 0.2 percent polyphosphate	89.5	+ 3.1	30.0

[1] 110 minute process @ 240°C.

TABLE 3.--Effect of additives in the soak water on water uptake and characteristics of the finished product (Batch B)

Additive in soak water	Water uptake	Weight gain (processed)	Shear value (processed)
	Percent	Percent	Gram
None	83.7	.0	30.3
0.5 percent polyphosphate	96.3	+12.3	17.0
0.2 percent polyphosphate	84.2	+ 3.1	23.0
1.0 percent NaCl	81.0	+ 4.4	19.0
0.5 percent NaCl	82.2	+ 2.4	22.2
1.0 percent NaCl + 0.5 percent polyphosphate	91.3	+20.4	13.0
0.5 percent NaCl + 0.5 percent polyphosphate	89.2	+10.9	14.8

TABLE 4.--Evaluation of commercial brands of pork and beans

Product brand	Shear value	Bean weight in processed can
	Gram	Percent
A	28.0	65.2
B	24.5	63.9
C	22.5	62.6
D	24.5	63.6
E	21.5	64.2
F	29.0	56.4
G	22.0	66.5
H	27.0	66.7
I	22.0	62.5
J	26.0	59.9

The different batches of beans were evaluated. The experiment confirmed that the addition of polyphosphates increased water uptake during the soaking process and that salt depressed it Two combinations of these additives (tables 2 and 3) produced abou the same levels of water uptake as the polyphosphates alone at the same concentrations.

The two batches differed in response to the additives with respect to bean volume in the finished product. While salt alone had a small negative effect on finished bean volume in the first batch, it caused small, but significant increases in the second batch. Addition of polyphosphates alone to beans from the first batch produced very high water uptake during the preprocess soak treatment, then lost this advantage during the thermal process, and finally resulted in a small negative effect on the finished bean volume. Beans from the second batch, however, maintained

the advantage gained during soaking through to the finished product. Similar observations were made on the shear values of the beans. In one case, addition of salt or polyphosphates alone resulted in toughening of the finished product, while in the other case it produced very tender beans.

Reasons for these differences in response to additives among different batches of beans were not sought in this investigation. However, this phenomenon may be associated with development of free fatty acids during storage. Combinations of the additives resulted in positive effects for both batches with response to bean volume and tenderness; and these effects carried through to the finished product. The corresponding gain in bean volume over that of a conventional process (110 minutes, no additives) ranged from 10 to 20 percent. Thus, despite a much shortened thermal process (50 minutes), beans soaked in the salt-polyphosphates combinations gave a more tender, higher yielding product than the conventional process.

The short thermal treatment also resulted in a bean lighter in color than that found in the commercial samples. A more severe heat treatment is evidently needed to develop the brown color usually associated with the product. Preliminary studies with EDTA showed that this compound tended to reduce color formation even further, giving the processed beans a very light color. We have not as yet attempted to overcome this problem, but it appears that accentuation of color can be accomplished by adding glucose to the sauce.

Heat penetration studies of sample No. 1 (table 2) have indicated that a 50-minute thermal process at 245°F. results in an F_o value of 20. This is more than adequate to render the product stable if bacterial load is not excessive.

CONCLUSIONS

Results of this investigation indicate that industrial applications of forced gas release to bring about rapid uptake of water are feasible, and that considerable shortening of both soak time and thermal processing time will result, provided tenderizing additives are supplied to the soak water. Substantial savings should be realized through more intensive equipment use, reduced labor costs, and higher yields of finished product.

FACTORS INFLUENCING THE COOKING RATE OF STORED DRY BEANS

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The work reported here is a continuation of the studies conducted by Herman J. Morris.[1] The materials and methods used were the same as those described in the earlier reports. It had been observed that some beans after storage took longer to cook than similar beans freshly harvested. However, there were few quantitative data on the rate of change in cookability or on the storage factors which influence it.

The purpose of the present study was to measure the effects of moisture content, temperature, and time on the speed with which presoaked beans of three varieties would cook tender. This work is unique in that an objective method of measuring cooking rate was used. In his first series of experiments, Morris used pinto, Sanilac, and large lima beans of the 1961 crop, adjusted to moisture contents ranging up to 14.4 percent and stored at 70° and 90°F. He later started a second series of experiments to explore the range of higher moisture contents and lower temperatures, and for this work beans of the same varieties but of the 1963 crop were employed. These were adjusted to moisture contents ranging up to 16.7 percent and were stored at 40°, 55°, and 70° for 2 years.

The cooking time results after various storage temperatures and bean moisture contents obtained with pintos and large limas are shown in figures 1 and 2. Sanilacs behaved in a similar way when stored up to 12 months but the data obtained at the longer storage periods show peculiar inconsistencies. Because of the possibility of experimental error, these results are not reported at this time.

The most striking conclusion to be drawn from the data is the very substantial change in cookability which may occur. For example, a sample of pinto beans stored for a year at 70°F. required

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[1]H. J. Morris. Cooking qualities of dry beans. Proc. Sixth Annual Dry Bean Conference, Los Angeles, Calif. Jan. 2-4, 1963.

H. J. Morris. Changes in cooking qualities of raw beans as influenced by moisture content and storage time. Proc. Seventh Research Conference on Dry Beans, Ithaca and Geneva, N. Y., December 2-4, 1964. U.S. Dept. Agr., Agr. Res. Service, ARS 74-32, 1964.

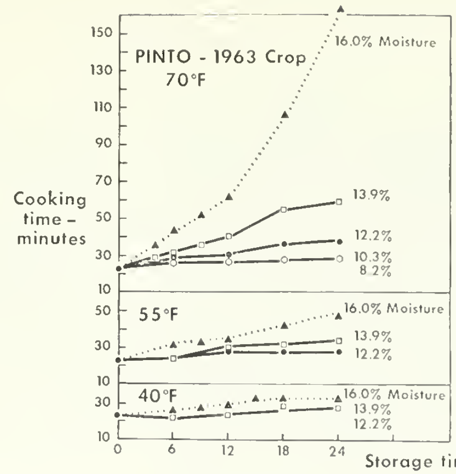

Figure 1

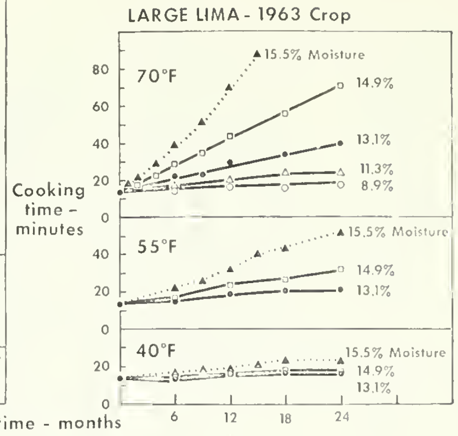

Figure 2

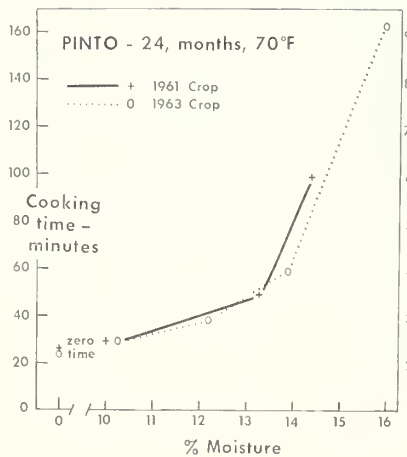

Figure 3

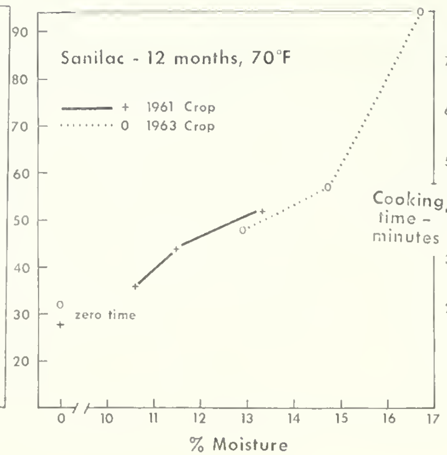

Figure 4

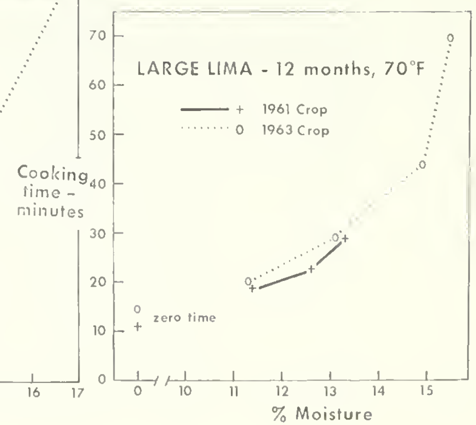

Figure 5

Figures 1 and 2.--Effect of factors indicated on cooking times. Figures 3 to 5.--Effects after storage.

62 minutes to cook tender after being presoaked, although, when freshly harvested a sample cooked tender in 23 minutes. Large limas initially requiring only 14 minutes for cooking needed 70 minutes after a year at 70°. In both cases the beans contained substantially less moisture than the 18 percent maximum permitted by grade standards. Smaller but definite changes in cookability occurred in beans stored at 55° and even at 40°F.

The initial cooking times and the cooking times after storage at 70° at various moisture contents are plotted in figures 3, 4, and 5. The closeness of the solid and broken curves indicates that beans of the same variety but of the 1961 and 1963 crops behaved in a generally similar manner. The marked effect of low moisture content in preserving the cooking quality of beans is readily apparent.

Beans for canning are given a long, high-temperature cook in order to achieve commercial sterility. However, we have been informed that occasional lots of beans will remain hard even under the severe heat processing used in canning. The loss in cookability in beans during storage may be even more serious in the case of dry beans marketed for home use. As beans move from the field at harvest, through storage and distribution, into the kitchen cupboard, and finally into the cooking kettle, they obviously are subjected to a wide range of temperature, moisture content, and storage time. Such movements and changes must inevitably lead to some packages of dry beans requiring much more time to cook than the average. If even occasionally a housewife buys beans that don't cook before dinner, she will think twice before buying them again. If the industry believes that this is a serious problem limiting their markets, such steps as artificial drying of high moisture beans, use of moisture-proof packaging, and refrigerated storage during the warm months should be considered.

THE DEVELOPMENT OF THE FLATULENCE PRINCIPLE IN THE MATURING BEAN

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and
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Immature green lima beans are reportedly flatulence-free, or contain much less flatulence activity than the same beans after reaching full maturity. This had not been previously demonstrated, however, by objective tests on human subjects. Our purpose was to determine whether this belief is true and, if so, to determine at what point the gas-forming principle begins to appear between the immature green and the dry mature lima.

If it could be demonstrated that the flatulence principle appears only after the bean begins to mature, it might then be possible to follow the development of this principle with known chemical changes in the maturing bean and perhaps isolate and identify the factor responsible for the formation of gas in the gut after a meal of cooked dry beans. The results of our work show that in the Ventura variety of lima bean, flatulence activity does not begin to appear until about 1 week before the beans are at the green mature stage and then continues to increase, reaching a maximum when the dry beans are ready for harvest. Fordhook limas, on the other hand, showed very little flatulence activity at either the green or the dry stage.

Two varieties of lima beans, Ventura and Fordhook, were grown in a test plot by the Agronomy Department of the University of California at Davis. Samples of beans were harvested once a week, beginning 3 weeks before the beans reached the green mature stage. These samples were assayed for flatulence by feeding to a panel of human subjects and periodically measuring breath hydrogen and rectal flatus for 8 hours following the bean meal. The volume and composition of rectal flatus were measured on the subjects by a portable apparatus developed in the Western Utilization Research and Development Division while breath hydrogen was measured by a chromatographic method developed by John Nielsen at the Stanford Research Institute, Palo Alto, California and Professor Doris Calloway, Department of Nutritional Science, University of California, Berkeley (see report of 5th Dry Bean Research Conference in Denver, Colorado).

Figures 1 and 2 represent a typical assay on one subject. The period of maximum gas production, both as breath hydrogen (fig. 1) and as rectal flatus (fig. 2), occurred about 4 to 5 hours after the subject ate a sample of cooked dry Ventura beans. Note that in each case as the beans matured there was a progressive increase of the peak representing maximum gas production.

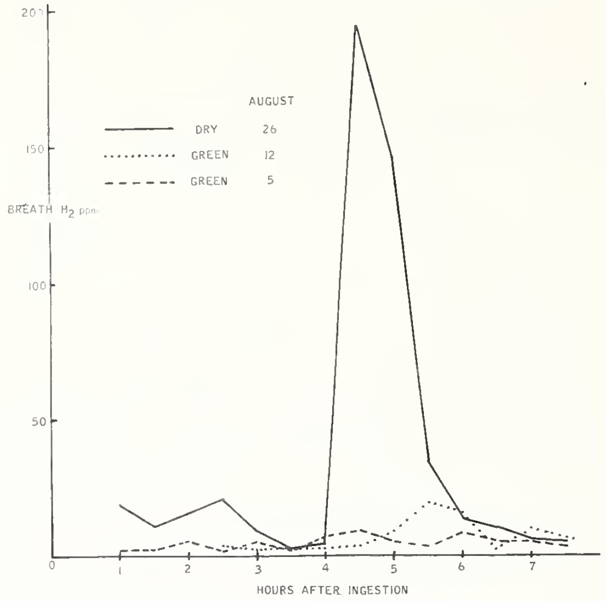

Figure 1.--Gas production, as measured by breath hydrogen, after a subject ate cooked, dry Ventura beans.

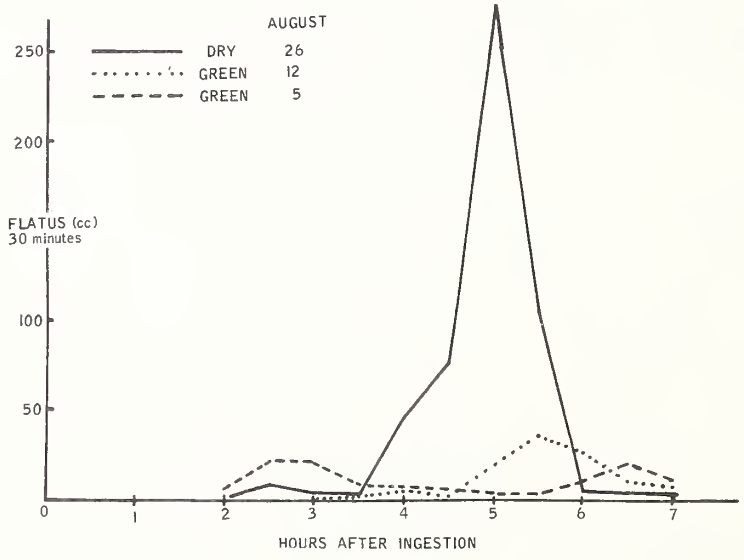

Figure 2.--Gas production, as measured by rectal flatus, after a subject ate cooked, dry Ventura beans.

Table 1 represents the total flatus obtained from three human subjects, labeled DC, RD, and BM, during the 3-hour period of maximum gas production following ingestion of the gas-forming food. The control formula meal is a known low-gas-producing mixture of egg white, sucrose, cornstarch, dextri-maltose, and salt developed at the Human Nutrition Laboratory of the University of California. Although the three subjects were selected at random, they illustrate one of the problems always encountered by investigators of flatulence and its variation in human response. These three subjects show a considerable variation in response to bean consumption, a variation similar to that encountered in the general population.

TABLE 1.--Flatus from lima beans

Varieties	Human subjects DC	RD	BM
	(Total volume (cc.) for 3-hour peak period)		
Fordhook			
Formula	50	0	19
Green mature	41	0	14
Dry	93	0	25
Ventura			
Dry	471	45	166

All subjects were fed a bean meal equivalent to 100 grams of dried Ventura lima beans or the contents of a No. 2 can. Subject RD's metabolism is such that he could eliminate practically all of the increased intestinal gas production resulting from the bean meal through his lungs, and there was no increase in rectal flatus. Subject DC, however, like many people, was unable to eliminate this increased gas through his lungs and there was an increase in rectal flatus. Subject BM is midway between these extremes. Since commercial dry limas are primarily Venturas, the results obtained in this experiment predictably paralleled previous assays on human subjects fed test meals of cooked commercial dry lima beans.

Using the same panel and procedures as described above, quite different results were obtained with Fordhook beans. The Fordhook is used chiefly as a frozen green immature product. Like the Ventura lima, the green immature Fordhook produces no significant increase in either breath hydrogen or rectal flatus after consumption. However, unlike the dry Ventura, the dry Fordhook has a relatively low level of flatulence activity.

Investigations are now under way to determine whether there is some difference in chemical composition between dry Fordhooks and dry Venturas which might account for this

difference in flatulence activity and to see if this reduced flatulence activity of the Ventura can be transferred to other varieties of beans by appropriate genetic selection.

WHAT A GROWER WOULD LIKE TO SEE IN DRY BEAN RESEARCH

John S. Cox
Lima Bean Advisory Board, Westley, Calif.

I can visualize no research effort being carried on today that does not directly benefit bean growers. Every type of research should be the growers' concern, whether it be in plant breeding, more efficient cultural practices, storage and handling factors that affect both appearance and cookability of beans, new and stronger markets, or more acceptable products for today's market demands. We farmers are of course most familiar with research on cultural practices, such as improved fertilizers and methods of application, more effective use of insecticides, better use of herbicides, and better planting, cultivation, and harvesting methods. These activities are important to us, and research in these areas should be continued and intensified. Growers also should not overlook the broader areas of concern that have economic and social significance.

We in California are, perhaps of necessity, particularly sensitive to economic, sociological, and technological changes that affect our agriculture. Despite California's rapid urbanization, it remains the country's leading agricultural State, and agriculture is its leading industry. Altogether, agriculture and related industries are estimated to contribute 15 billion dollars to the California economy every year, and to support one of every three jobs in the State.

How is this possible, with cities and suburbs swallowing some 375 acres of open land every day? This is possible partly because farmland is vastly more productive than ever--with mechanization and increases in size of farm, and investment. But the most important factor in California farm productivity--and a major element in the high investment per farm--is the farmers' eager acceptance of new ideas discovered in University and USDA laboratories, tested in field stations, and spread throughout the State by Agricultural Extension Service and other agencies.

We lima bean growers of California have become aware of the need to analyze trends. Urbanization rapidly replaces crops with concrete, causing the lima bean producers to transfer to areas less suited for present varieties. This shift is directed from the southern California coastal areas to sections of the western part of the San Joaquin Valley. Repeatedly we have observed that farming has yielded to other land uses, and farmers have gone elsewhere, thereby creating increases in land values and taxes in the new areas in which they settle. Production costs have also followed the inflationary spiral. We are also aware that consumer preferences have changed in recent years, and that convenience foods are here to stay. We in the bean business have a somewhat old-fashioned product to offer, from these standpoints. We must make some rapid changes of our own, in order to keep pace with those of our consumers, or be left standing in the barn while the race is run.

To meet these economic and sociological realities, it has become evident to California lima bean growers that at least three things must be done by a united lima bean industry: (a) Improve the yielding ability and quality of our bean varieties for all areas of lima bean production; (b) improve the acceptability of our products; and (c) publicize and promote these achievements as they occur. We hope the result will be an increase in both volume and selling price of our beans.

Having had these three objectives in mind, producers, warehouse handlers, and dealers in California in 1951 initiated the California Lima Bean Marketing Order, a legal entity under the California Agricultural Marketing Act of 1937. This Order was initiated voluntarily by the industry as an expression of desire to organize itself to help itself. The Order and its objectives were developed by the industry, with the concurrence of the State Director of Agriculture. All policies and programs are formulated, financed, and administered by the Lima Bean Advisory Board, which is composed of democratically elected representatives of lima bean growers, handlers, and dealers in each of three districts of California.

It is our feeling that a composite group of dedicated people, representing all interests, can best focus effective attention on the problems common to us all. As a grower representative on the Board, I wish to acknowledge the guidance offered us through the wise counsel of bean handlers and dealers on the Advisory Board. Also, all of us on the Board recognize the irreplaceable advice and assistance of our manager, Gordon Monfort, in helping us direct our course of action. Gordon has unique qualities of leadership and experience that we just cannot do without.

The California Lima Bean Marketing Order is designed to provide a method by which, if desired, any of the following activities may be employed: (a) Investigation, recommendation, and establishment of volume control regulations. (b) Recomendation and establishment of grade regulation and quality-control inspection. (c) Establishment of sales promotion, market development, and distribution research. (d) Establishment of production and processing research. (e) Establishment of annual budget and compensating assessment. (f) Collection and disposition of funds.

In exercising the above options, the Advisory Board to date has not felt the need for any volume control. The lima bean industry today is in fairly good balance as far as supply and demand are concerned. The needs of an increased national population tend to be offset by its lower per capita consumption of beans and by technological advances in production methods. Also, we are told that many areas of the world today suffer from malnutrition. Those areas could beneficially utilize the rich protein in our beans. Therefore, stimulation of additional consumption of beans, both at home and abroad, should be our emphasis, in order that all mankind might benefit from our successful production efforts.

The Lima Bean Advisory Board, in order to increase the general acceptance of our beans, has instituted quality control measures that have upgraded our product. Beginning with the 1964 crop and extending over the 1965 and 1966 crops, the Board established minimum grade regulations that limit the sale of beans into the domestic food channels to grades of U.S. No. 2 or better. While some growers and handlers had some misgivings about these regulations at first, our recent Board surveys show that no undue hardships have been imposed on growers and handlers of good beans, and that acceptance of limas in the market has been improved by these measures. The assurance of uniform high quality and the restrictions on trading of substandard beans have favorably affected the price structure during this period.

In the fields of sales promotion and market development, the Board is fortunate in being able to utilize the special talents and experience of its manager. Gordon has spent much time and effort in direct contacts with food editors of national and local newspapers and magazines. Our "Lima Bean Story" and recipes using lima beans which have recently been developed by our consulting home economist, Mrs. Geneveve Callahan, together with color transparencies showing actual food dishes, beautifully displayed, have all been enthusiastically received by the aforementioned editors. A program of furnishing high school and junior college home economics classes with both a small supply of beans and

improved menus has been carried on in southern California for the purpose of acquainting a whole new generation of food buyers with a fresh approach to the uses for dry lima beans. Our manager has also had occasion to conduct a market survey of potential areas of sales of lima beans in European countries in conjunction with his attendance at the World Trade Fair in London in early 1963. He reported that some prospects exist for additional outlets, particularly if we are able to improve the uniformity of seedcoat color and general quality factors.

Our activities in the area of production research have led the Board into contracts with the University of California's Agronomy Department and the University of Hawaii. Merton Love, Chairman of the Department of Agronomy, and Robert Allard, a plant geneticist, at the University of California, Davis, have both been extremely generous and helpful in supervising the varietal research work at Davis, the South Coast Field Station near Santa Ana, Calif., and the University of Hawaii research farm near Honolulu. Formal station plots and grower field plots in both southern California and in the Central Valley areas of California have been fruitful. The conduct of research efforts at the South Coast Field Station have been under the capable direction of Carl Tucker, and similar work at Davis and San Joaquin Valley fields is under the direction of Roland Sanchez. The University of California, through the experience and efforts of all these men, has furnished us with time, materials, and knowledge far beyond our ability to repay. For their generous service, the California Lima Bean Advisory Board is most grateful. The varietal work in each of these areas continues to be directed toward nematode resistance, earliness of maturity, uniform white seedcoat, increased vigor, and yielding ability. Research in nematology has been conducted in Hawaii because in that region two generations of plants can mature each year. Also, the severe infestation of nematodes there will guarantee almost perfect immunity when these improved strains of beans are brought back to California. Mr. Sanchez, who has recently returned from harvesting his latest bean crop in Hawaii, indicates that the introduction of nematode resistance into our commercial varieties of limas is imminent. Carl Tucker and others have given lima bean growers for the first time in 1965 a commercial lima bean variety of equal yielding ability as compared to our present varieties, but with the additional desirable qualities of early growth and maturity and a uniform white seedcoat. This new strain has received good acceptance by both the trade and the growers who have grown it. Other releases will follow in order, I am sure.

Processing research has been directed toward a greater acceptance of beans by the consumer. Attempts to improve the cookability and digestibility of beans, as well as the development

of convenient bean products, are being conducted under Board contracts with the Western Utilization Research and Development Division of USDA in Albany, Calif., and in its Fruit and Vegetable Chemistry Laboratory in Pasadena. Research is being conducted in these laboratories in the fields of sensory evaluation of beans and bean products, factors of storage and handling that affect quality and cookability of dry beans, and the development of more acceptable bean products. Director M. J. Copley of USDA's Western Utilization Research and Development Division has been extremely helpful and understanding of our needs; and his conscientious supervision of bean processing research has been rewarding. Here again, the lima bean growers have been the beneficiaries of a wealth of materials and skills that are being provided above and beyond our contractual contributions. Under Director Copley's guidance, work at Albany, Calif., has been conducted by H. K. Burr, E. H. Murphy, Herman Morris, and others. Work at Pasadena is under the direction of E. A. Beavens and L. B. Rockland. Much has been achieved by all these men, and lima bean growers see the need to continue this exploration. Increased emphasis on the problems of flatulence and consideration of the improvement of the nutritional qualities of lima beans might now be justified.

In order to carry out the stated objectives of our Board, it is evident that a budget must be prepared and adhered to. Annually, the Board evaluates present activities, and after a survey of the potential production of lima beans for the coming crop year, an assessment is approved which will provide the funds necessary to conduct the selected activities. This assessment is imposed on a per-bag basis, uniformly over the entire State on all limas produced in the year concerned, and the annual assessment in the past has averaged $100,000. I believe that it is now self-evident that growers of lima beans in California are indeed interested in research and are willing to support such work.

Perhaps I would be less than candid if I did not admit that there are some growers who wish we could wrap up the currently financed research projects, get some pat answers, put them directly into practice, and then forget about future assessments for research. Those growers are, I believe, a dwindling minority. Farmers today, at least in California, have come to recognize the inevitability of change for progress, the absolute necessity of looking to the future, and the desirability of having a hand in shaping that future. It is generally estimated that an engineer's knowledge becomes obsolete within 5 to 10 years. While a farmer's reservoir of facts and practices may serve him a somewhat longer period, sooner or later these will also become at least partly outdated. The grower who fails to recognize this does so at some peril to

himself and the general economy. Thus it is that continuing research and technological studies are essential for orderly progress. As agriculture continues to be one of our most basic industries, so the support for agricultural research should be broadly based.

Even though bean growers in California and throughout the country, with support from the entire bean industry, have brought into being many valuable research projects, others of potential value will be revealed as time goes on. Those of you who work in the scientific area are perhaps better qualified than I to name those areas of potential value for further study. However, speaking for growers, I wish to acknowledge the great importance which we attach to your efforts and our true appreciation of the results.

Alfred North Whitehead said nearly fifty years ago (and the wisdom of his statement is perhaps more apparent today than it was then): "In the conditions of modern life, the rule is absolute: the race which does not value trained intelligence is doomed... Today we maintain ourselves; tomorrow science will have moved forward yet one more step, and there will be no appeal from the judgment which will be pronounced on the uneducated."

PHYTOHEMAGGLUTININS IN DRY BEANS

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Early investigators in nutrition were fully aware that certain legumes were very poor sources of protein unless subjected to heat treatment. From these observations arose the realization that those legumes must contain substances which, unless inactivated by heat, can interfere with normal growth of animals, and can even cause death after prolonged ingestion.

The first toxic substance to be studied in detail was a protein isolated from the castor bean in 1888 and given the name <u>ricin</u> (7). Injection of only a few micrograms of ricin is sufficient to cause death of experimental animals within a few hours. Aside from its extreme toxicity, ricin proved to be able to cause clumping together of a suspension of red blood cells. This phenomenon is referred to as <u>hemagglutination</u>, and the substances producing this effect are called <u>hemagglutinins</u>. Because of their

origin, hemagglutinins found in plants are referred to as phytohemagglutinins. Another toxic photohemagglutinin was subsequently isolated from the jack bean by Sumner in 1919 (8), who called this protein concanavalin A.

It soon became evident that these hemagglutinins were widely distributed in the plant kingdom particularly among the legumes, including such edible species as the navy bean, lima bean, kidney bean, soybean, and lentils. It is interesting to note that most of these legumes are likewise poor sources of protein unless they are properly cooked. With the discovery that these legumes also contained heat-labile proteins which could inhibit the enzyme trypsin, attention was diverted from the hemagglutinins, and the so-called trypsin inhibitors became prime suspects as the cause for the poor utilization of the protein from these legumes in the uncooked state.

The hypothesis that the trypsin inhibitor is responsible for the poor nutritive value of raw legumes is a logical and attractive one, because one could postulate that the trypsin inhibitor is simply interfering with the normal digestive processes in the intestinal tract and is thus producing a less efficient utilization of the dietary protein. Somewhat disturbing, however, was the observation that there is apparently no clear-cut relationship between the trypsin inhibitor content of various legumes and the beneficial effect which heat has on their nutritional value (1). It was in fact this lack of correlation that led our own laboratory about 10 years ago to embark in research on factors other than the trypsin inhibitor that might be responsible for the poor nutritive value of most legumes in their raw state.

Because of their importance in livestock and human feeding, our first studies were done with soybeans. This legume illustrates in a very vivid manner the beneficial effect which heat has on the nutritive value of this protein (table 1). Drawing upon the earlier observations that soybeans are known to contain a hemagglutinin, we directed our efforts toward the isolation of this hemagglutinin in pure form. This material was added at a level of 0.8 percent, to a diet containing 25 percent autoclaved soybean meal. This level was calculated to provide the same hemagglutinating activity as 25 percent raw soybean. The diet was fed to rats for 2 weeks. Table 1 suggests that the soybean hemagglutinin accounts for approximately one-half the growth inhibition that one observes with raw soybeans when compared with the heated meal. It is clear that the growth inhibition one obtains on raw soybeans can be only partly attributed to the hemagglutinin and that some other factor, most likely the trypsin inhibitor, is also involved. In fact feeding a purified preparation of the trypsin inhibitor to rats also gives about 50 percent growth inhibition (6), and the combination of the trypsin inhibitor and hemagglutinin gives the same growth as the raw meal.

TABLE 1.--Growth inhibitory effect of the soybean hemagglutinin (SBH)[1]

Protein component of diet	Weight gain	Growth inhibition
	Pound	Percent
25 percent heated soybean meal[2]	60.0	0
25 percent raw soybean meal	28.0	43.2
25 percent heated soybean meal + 0.8 percent SBH[2]	45.0	25.6

[1]Taken from Liener (5).
[2]Autoclaved at 15 pounds for 15 minutes.

Although the soybean is an important ingredient of livestock rations, legumes other than soybeans constitute an important source of dietary protein for large segments of the world's population, particularly in those countries in which the consumption of animal protein is limited by its nonavailability or self-imposed because of religious or cultural habit. We, therefore, turned our attention to species of legumes that enjoy popular consumption in some of the less developed countries. For this purpose we were able to secure samples of a black bean from Guatemala, Bengal, and red gram from India, mung bean from the Philippines, and, for comparative purposes, the domestic kidney bean.

We first established whether heat treatment would effect any improvement in the nutritive value of the various beans. As shown in table 2, the growth-promoting values of only the black bean and kidney bean were enhanced by heat treatment. Both beans in the raw state caused the death of all of the experimental animals within 2 weeks. Although autoclaving (15 pounds pressure for 15 minutes) prevented this mortality, the animals grew very slowly and, in some instances, lost weight. But beans which had been soaked in water overnight prior to autoclaving produced a normal rate of growth which was equivalent to that obtained with casein.

If a comparison is made of the hemagglutinating and antitryptic activities of crude extracts of these legumes (table 3), it is significant to note that the two unheated legumes that were toxic, namely the black bean and kidney bean, were likewise the only two that displayed hemagglutinating activity. For this reason subsequent studies were directed to the purification of the hemagglutinins from those two beans and to the effect which such fractions might have on the growth of experimental animals. Purified preparations of the black bean hemagglutinin (BBH) and kidney bean hemagglutinin (KBH) were fed at various levels to rats on a basal diet containing 10 percent casein as the source of protein. The results are shown in table 4. A definite

TABLE 2.--The effect of heat on the nutritive value of some legumes[1]

Source of protein[2]	Gain or loss in weight (grams per day) Raw	Autoclaved	Soaked and autoclaved
Phaseolus vulgaris:			
Black bean	[3]-1.94	+0.24	+1.61
Kidney bean	[4]-1.04	-0.41	+1.48
Cicer arietinum:			
Bengal gram	+1.25	+1.16	--
Cajanus cajans:			
Red gram	+1.33	+1.74	--
Phaseolus aureus:			
Mung bean	+1.05	+1.07	--
Casein	+1.57	--	--

[1]Data taken from Honavar and others (3).
[2]Beans were fed at a level providing 10 percent protein.
[3]Animals lived 4 to 5 days.
[4]Animals lived 11 to 13 days.

TABLE 3.--Hemagglutinating and antitryptic activities[1]

Legume	Hemagglutinating activity[2]	Antitryptic activity[2]
	HU/ml.	TIU/ml.
Phaseolus vulgaris:		
Black bean	2,450	2,050
Kidney bean	3,560	1,552
Cicer arietinum	0	220
Cajanus cajan	0	418
Phaseolus aureus	0	260

[1]Data taken from Honavar and others (3).

[2]HU = hemagglutinating units, and TIU = trypsin inhibitor units as defined by Honavar and others (3).

inhibition of growth was apparent at levels as low as 0.5 percent of the diet, although, in the case of the black bean, this level did not cause the death of any of the animals. Growth inhibition was much more marked at this level with KBH than with BBH. In fact KBH at a level of 0.5 percent caused 100 percent mortality after about 2 weeks; 1.2 percent of BBH was necessary to produce a similar rate of mortality. It would appear that KBH is about 2 to 3 times as toxic as BBH. Samples of the hemagglutinin which had been inactivated by boiling did not exert any appreciable effect on growth at a level (0.5 percent) which was inhibitory in the case of the unheated protein.

TABLE 4.--Effect of purified hemagglutinin fractions from the black bean and kidney bean on the growth of rats[1]

Source of hemagglutinin	Purified hemagglutinin in diet	Average gain in weight	Mortality[2]
	Percent	g. per day	Days
Black bean	0.0	+2.51	
	.5	+1.04	
	[3] .5	+2.37	
	.75	+0.20	
	1.2	-0.91	15-19
	2.3	-1.61	12-17
	4.6	-1.72	5-7
Kidney bean	0.0	+2.31	
	.5	-0.60	13-16
	[3] .5	+2.29	
	1.0	-0.87	11-13
	1.5	-1.22	4-7

[1]Data taken from Honavar and others (3).

[2]100 percent mortality observed during period recorded here. Blank space indicates that no deaths were observed.

[3]Solution of hemagglutinin boiled for 30 minutes and dried coagulum fed at the level indicated. Hemagglutinating activity was completely destroyed by this treatment.

Experiments with chicks showed that this animal was also sensitive to the toxic effects of the kidney bean (table 5). Kidney beans at a level of 50 percent of the diet seriously retarded their growth although mortality did not result as in the case of the rat. In contrast to studies with rats where it was found necessary to soak the beans prior to autoclaving in order to achieve satisfactory growth, this study showed that preliminary soaking was unnecessary for chicks. The reason for this difference in the response of the two species is unknown. When KBH was added to a diet composed of corn and soybean meal at a level of 1 percent, there was about 19 percent inhibition of growth compared to the 79 percent inhibition produced by the raw bean. In the case of the chick, therefore, toxic factors in addition to the hemagglutinin must be responsible for the poor nutritive value of the raw bean. To what extent the trypsin inhibitor might be responsible for those other effects was not demonstrated directly. In experiments shown in table 6, however, it was found that supplementation with amino acids which might be limiting in kidney-bean protein (methionine, arginine, valine, glycine, and phenylalanine) failed to improve growth on either the raw or autoclaved bean.

TABLE 5.--Effect of the kidney bean hemagglutinin (KBH) on growth and the size of the pancreas of chicks[1]

Dietary treatment	Average weight gain[2]	Growth inhibition	Weight of pancreas
	Gram	Percent	g./kg. body wt.
Kidney beans (50 percent of diet):			
Soaked and autoclaved	85	--	4.78
Autoclaved	83	79	5.02
Raw	18	--	7.11
Basal diet[3]	109	19	4.87
Basal diet + 1-percent KBH	88	--	5.02

[1]Data taken from Wagh and coworkers (9).

[2]Experimental period of 12 days; 5 chicks per group.

[3]Contains 22.9 percent protein derived from corn and soybean meal.

TABLE 6.--Effect of amino acid supplementations on kidney bean diets fed to chicks[1]

Diet	Weight gain
	Gram
Corn-soybean	123
Raw kidney bean	18
Raw + amino acids[2]	22
Autoclaved kidney bean	83
Autoclaved + amino acids[2]	85

[1]Data taken from Wagh and coworkers (9).

[2]It was necessary to add the following amino acids in order to bring each amino acid to at least the level found in the corn-soybean diet: methionine, arginine, valine, glycine, and phenylalanine.

An enlargement of the pancreas is a characteristic response of animals to the trypsin inhibitor of soybeans (2). It will be noted from the data of table 5 that raw kidney beans likewise produce pancreatic hypertrophy which can be largely eliminated by autoclaving the bean. It is significant to note, however, that pancreatic hypertrophy did not accompany the growth inhibition which was obtained with KBH. This would indicate that the growth depression caused by KBH is entirely unrelated to any effects which the trypsin inhibitor might have on the organism.

As to the mechanism whereby the hemagglutinin may exert its adverse effect on growth, present evidence would suggest its site of action to be the lining of the intestinal tract. Jaffé (4) noted a definite impairment in the absorption of protein and fat

when rats were fed raw black beans or the hemagglutinin purified therefrom. He furthermore was able to show that isolated intestinal loops taken from rats fed the raw bean or the purified hemagglutinin absorbed glucose at about half the rate of loops taken from control animals. These results would indicate that the action of the hemagglutinin might be to combine with the mucosal cells lining the intestinal wall, thus interfering with the absorption of essential nutrients.

With the current concern for the future feeding of the expected increase in world population, our attention is being focused more and more on the legumes as a cheap, readily available source of dietary protein. One of the factors that will certainly have to be considered in this connection is the nutritional significance of their toxic constituents, of which the phytohemagglutinins are but one example. It is indeed fortunate that this particular substance can be eliminated by the simple expedient of adequate heat treatment. But we cannot choose to ignore the fact that there may be other toxic constituents in legumes of which we are presently not aware, and any program that envisions the expanded use of legumes as a supplementary source of protein in the world of tomorrow must take cognizance of this possibility.

Literature Cited

(1) Borchers, R., and Ackerson, C. W. Arch. Biochem. 13: 291, 1947.

(2) Chernick, S. S., Lipkovsky, S., and Chaikoff, I. L. Am. J. Physiol. 155: 33, 1948.

(3) Honavar, P. M., Shih, C.-V., and Liener, I. E. J. Nutrition 77: 109, 1962.

(4) Jaffé, W. G. Artz. Forsch. 12: 1012, 1961.

(5) Liener, I. E. J. Nutrition 49: 527, 1953.

(6) ____________ Deuel, H. R. Jr., and Fevold, H. L. J. Nutrition 39: 325, 1949.

(7) Stillmark, H., Inaug. Diss. Dorpat, E. J. Karow, 1888. Cited by Osborne, T. B., The Vegetable Proteins, Longmans, Green and Co., New York, 1909.

(8) Sumner, J. B. J. Biol. Chem. 37: 137, 1919.

(9) Wagh, P. V., Klautermeier, D. F., Waibel, P. E., and Liener, I. E. J. Nutrition 80: 191, 1963.

CHANGES IN SUCROSE, RAFFINOSE, AND STACHYOSE DURING TEMPEH FERMENTATION

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The title of this paper indicates that sugar changes during fermentation of soybeans to prepare tempeh will be discussed, but some features and properties of sugars present in legumes in general will be included. It is hoped that thus the paper will be made more meaningful to persons who have varied interests in the dry bean industry.

When sugars are mentioned, those that first come to mind are glucose, fructose, and sucrose, because, as free sugars, they are by far the most widely distributed in nature. They are present in many foods of plant origin and, upon ingestion, are usually metabolized completely, serving as a primary source of energy. In certain plants, however, complex series of sugars may be present. Of special interest is a group of sugars which Professor French, at Iowa State University, calls the "raffinose family of oligosaccharides." They are higher-molecular-weight compounds found in legume seeds and in many other plants. We refer to these sugars as the "galactosido-sucrose" series of oligosaccharides. When found, those which occur in highest concentration are mono- and digalactosidosucrose, or raffinose, and stachyose respectively.

The tetrasaccharide stachyose is shown in figure 1. It is made up of the three simple sugars--fructose, glucose, and galactose. These simple sugars are joined in such a manner that

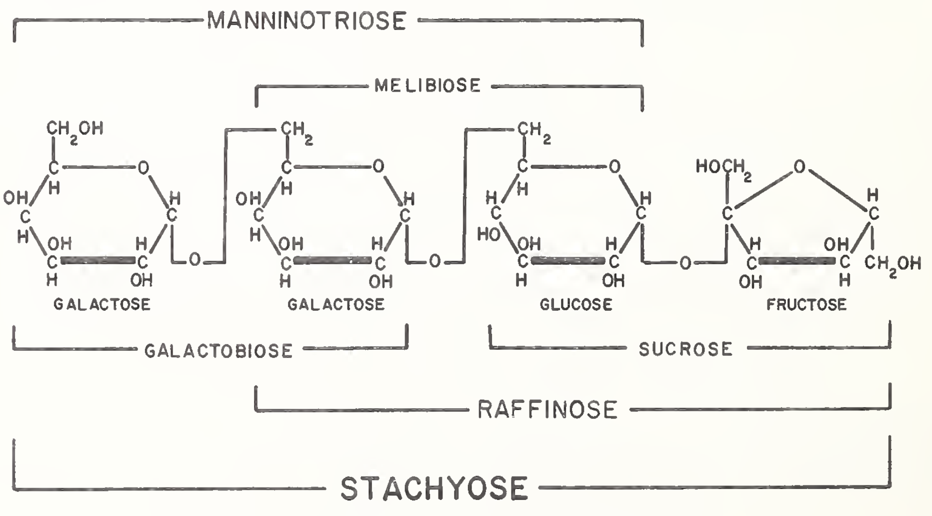

Figure 1.--Structure of stachyose.

stachyose may be thought of as containing the nonreducing sugar moieties sucrose and raffinose, and the reducing oligosaccharide moieties galactobiose, melibiose, and manninotriose. At present, interest in stachyose is largely academic, because it is available commercially only in small quantities and at rather high cost. However, we have been fortunate in being able to crystallize it in kilogram lots from extracts of the Japanese artichoke.

When the galactosido-sucrose series of sugars are ingested, their metabolic fate is uncertain. In order to be metabolized completely, two initial enzymes are required--an invertase, or sucrase, to hydrolyze the sucrose moiety of these oligosaccharides, and an α-galactosidase to hydrolyze the remainder of the molecule. Mammals do not possess an α-galactosidase in the gastrointestinal tract. While an invertase is present, which hydrolyzes free sucrose, it is a very particular kind. Essentially it is a "glucosido-invertase," and the glucose moiety of sucrose cannot be substituted, because the enzyme must attach to this unit in order to hydrolyze the molecule. Presumably, then, the human is not able to utilize the galactosido-sucrose series of sugars, when these are ingested.

Recognizing that the sugars described are usual components of legume seeds, let us turn to the use of soybeans as food in the Orient. Tempeh is a fermented soybean product widely consumed in Indonesia. It is prepared by inoculating cooked soybeans with a Rhizopus mold species and allowing the beans to ferment. Tempeh is digested more readily than cooked soybeans.

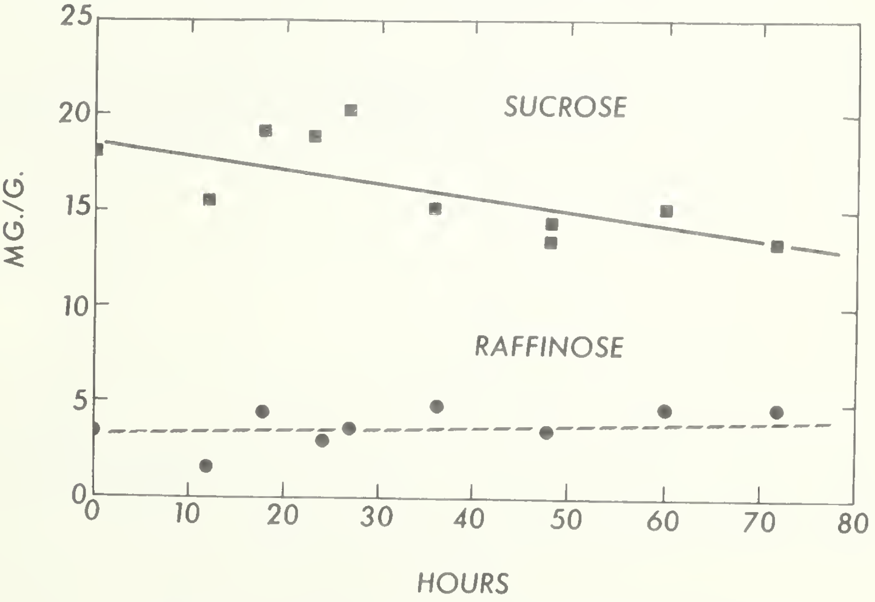

Figure 2.--Change in sucrose and raffinose concentration during tempeh fermentation.

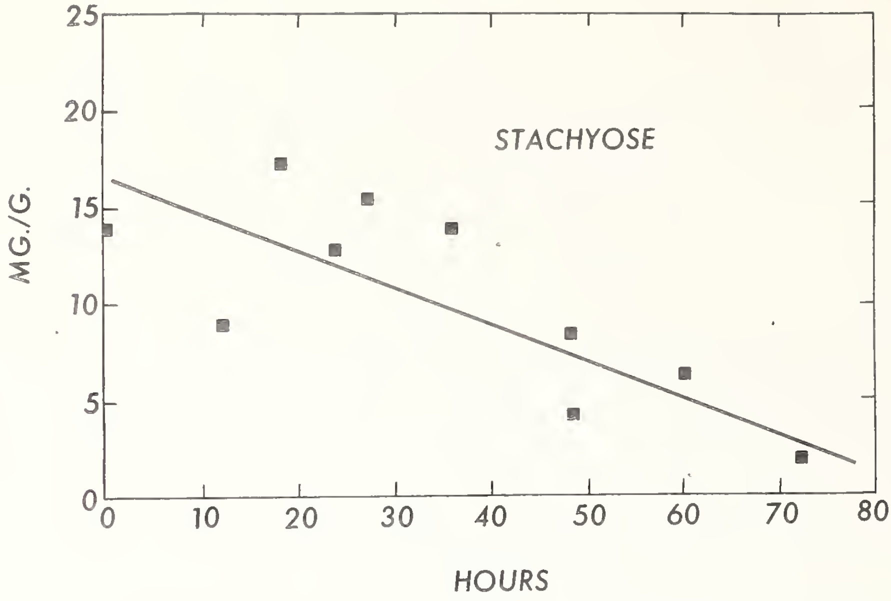

Figure 3.--Change in stachyose concentration during tempeh fermentation.

A number of biochemical changes are known to occur during the fermentation of soybeans, but the fate of individual sugars is uncertain. Consequently, we attempted to monitor the changes in individual sugars during tempeh fermentation of a single lot of soybeans. Using authentic sucrose, raffinose, and stachyose standards, and quantitative paper chromatographic techniques, the sugar composition of raw and cooked soybeans was determined as shown in table 1. Soaking and cooking the soybeans cut the sugar content by about 50 percent, largely at the expense of sucrose.

TABLE 1.--Sugar composition of raw and cooked soybeans

Sugar	Percent dry basis of: Raw soybean	Cooked soybean
Sucrose	4.53	1.84
Raffinose	.73	.35
Stachyose	2.73	1.40
Glucose	trace	--
Galactose	Do---	--
Fructose	Do---	--

After inoculation of the cooked soybeans with the Rhizopus mold, tempeh samples were taken at various time intervals over 72 hours. These were quickly frozen, lyophilized, and ground in preparation for sugar extraction and analysis.

Quantitative determination of individual sugars present in tempeh at various stages of the fermentation is shown in figures 2 and 3. Sucrose concentration decreased slightly over a 72-hour

fermentation time, while raffinose appeared to be at a steady-state concentration throughout the study. This result is comprehensible only if there is both α-galactosidase activity and fructosido-invertase activity present in the system, and raffinose is formed from stachyose about as rapidly as it is being hydrolyzed. In addition, the activity of the α-galactosidase needs to be greater than invertase activity, and melibiose should appear at some stage of the fermentation. Figure 3 shows that stachyose decrease is about twice as rapid as that for sucrose, and that stachyose is nearly absent after 72 hours. During the fermentation a reducing disaccharide appeared which attained maximum concentration (0.5 percent) after about 35 hours of fermentation and was absent after 60 hours. Co-chromatograms with known standards and preparation of phenylhydrazone derivatives for comparison of melting points and mixed melting points established the identity of the reducing disaccharide as melibiose.

THE MEASUREMENT OF HUMAN FLATULENCE

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For the past three years we have used a flatulence assay technique with human subjects to measure the flatus egested after meals of cooked dry beans. For comparison, it was necessary to establish the normal or average gas production in the human gastrointestinal tract. This paper presents results measured as flatus and breath hydrogen under the conditions of no food intake and low-gas and high-gas forming foods. The data were obtained on the same subject and therefore suffer from possible over-simplification and lack of variation encountered with a larger number of experimental samples.

Gases formed in the gastrointestinal tract are eliminated from the body primarily in respiration or as flatus. The flatus was measured by a portable carbon dioxide absorption apparatus and gas chromatography (1). Nielson reported to the Fifth Dry Bean Research Conference that the hydrogen gas component of the breath rises after a test meal of beans. His method has been applied to several foods by Calloway (2) and is essentially the technique adopted by this Laboratory because of the excellent correlation between breath hydrogen and flatus measurements.

In figure 1 are the results of flatus measurements. The effect of fasting in this subject (no food taken after 10 p.m. on the night before) was a low and relatively constant rate of gas egestion (av. 5.8 cc./hr., total 69 cc./12 hr.). The significance of the slight elevation at 6 hours is unknown. It may be that the stomach is not free of food material during this relatively short fasting period or that the digestive process continues, utilizing the intestinal secretions and mucosal sloughing of the gut wall. The blandness of the formula diet fed as a control meal is demonstrated by the comparable low flatus production (av. 9.1 cc./hr., total 110 cc./12 hr.). Three formula meals were fed: at 8 a.m., 12 noon, and 5 p.m. The small elevations in flatus egestion that occurred at 6 and 10 hours after the start of the assay are the effects of the breakfast and noon meals.

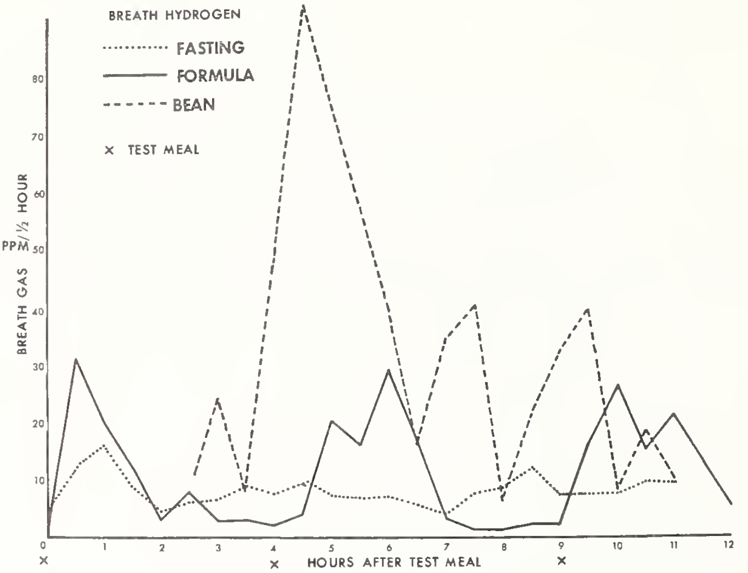

Figure 1.--The measurement of human flatulence.

The major components of rectal gas during fasting or after a bland meal are oxygen and nitrogen. That these gases are swallowed air is best indicated by experiments conducted at Stanford Research Institute, Palo Alto, Calif., by Calloway and Mathews (3), as reported to the Seventh Dry Bean Research Conference in which the ratio of nitrogen to argon in flatus was equivalent to that in air. Minor constituents are carbon dioxide and sometimes methane or hydrogen in decreasing order.

Much more spectacular are the flatus measurements after a test meal of cooked dry beans. No elevation in gas production occurs for about 4 hours after the beans are eaten. Because of this fact a husband might enjoy a hearty meal of beans at noon

and go home in the evening and blame the results upon some inoffensive delight that his wife prepared. More significant, however, is that researchers testing the flatulence qualities of foods should extend their measurements to include all of the effects of one single test meal. With most test subjects, the maximum elevation in flatus egestion occurs 5 to 6 hours after the meal is eaten. This primary flatulence lasts only 1 to 2 hours. Then gas production falls precipitously to a normal level. About 9 to 10 hours after the test meal of beans, a second short period of elevation occurs. Because of the probable location of the bean meal in the colon at this time, this gas production may arise from microbial fermentation of the unabsorbed residue of the bean meal. The gases which make the major contribution to flatulence from beans are carbon dioxide and hydrogen.

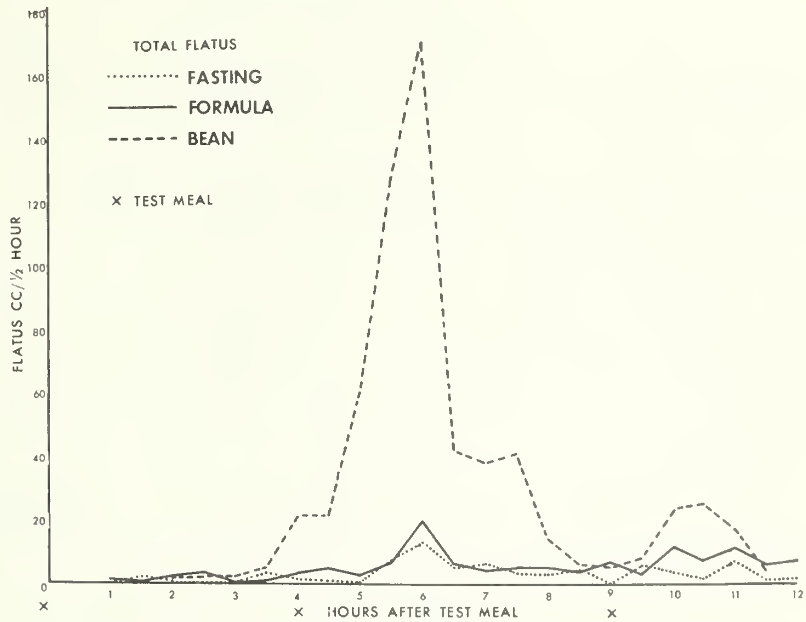

Figure 2.--The measurement of human flatulence.

Figure 2 presents the breath hydrogen measurements. After a slight early morning elevation, the level of hydrogen in the breath is low and constant. This "early morning peak" has occurred in all of our laboratory measurements and its origin is yet to be fully explained. According to Calloway (4) this is a result of nocturnal gas accumulation in the gastrointestinal tract during a period of reduced activity and blood flow and is eliminated in respiration upon arising. On a formula diet the most outstanding characteristic evident in the hydrogen component of the breath is the almost immediate elevation which lasts for 2 to 3 hours after each formula meal is eaten. Assuming that hydrogen is a product of microbial metabolism, a significant population must be so located in the colon as to be in active competition for the readily digested and absorbable sugars contained

in the formula (sucrose and maltose). Otherwise the level of hydrogen in the breath remains on a low and constant level. After a meal of beans the hydrogen in the breath rises rapidly 5 to 6 hours after the test meal is eaten. This period of 4- to 5-fold increase in hydrogen concentration occurs simultaneously with the increase in flatus egestion and therefore is not only an indispensable measurement to be used in the assay of flatulence but can be used as the only indicator of flatulence in cases where rectal collection of flatus is inconvenient or contraindicated.

Breath methane was measured but not included in this presentation because it is eliminated in the breath at a constant rate and shows no correlation with the egestion of flatus on a bean diet.

Literature Cited

(1) Proceedings of the Seventh Dry Bean Research Conference, December 2-4, 1964, Ithaca, New York.

(2) Calloway, D. C. Gastroenterology 51: 383, 1966.

(3) Personal communication.

(4) Personal communication.

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